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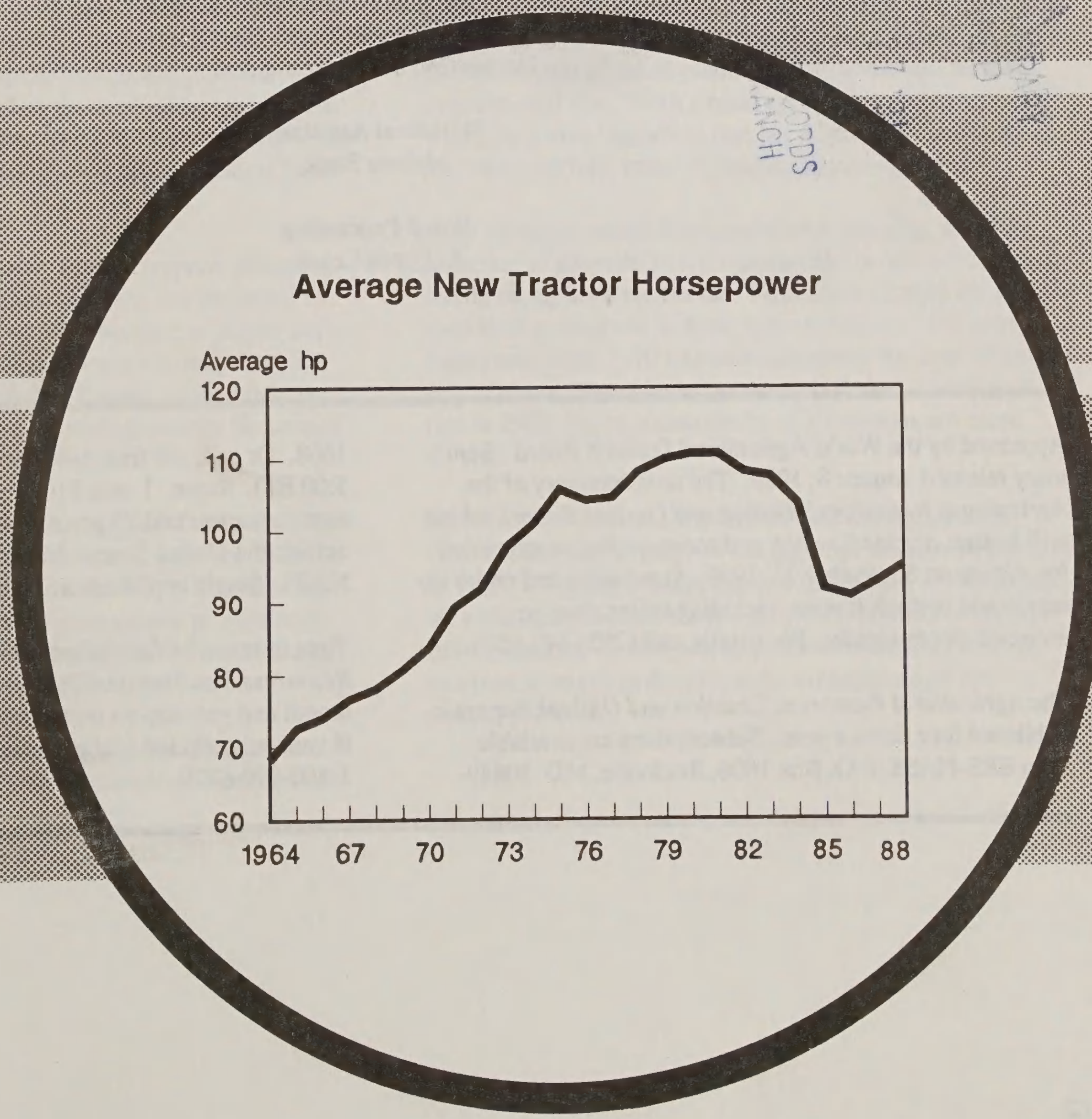

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Summary

Farm machinery sales are expected to increase for the third consecutive year, rising from $6.0 billion in 1988 to $6.2-$6.7 billion in 1989. An increase in planted crop acreage has helped strengthen sales this year. Trends that began in 1987, such as higher net cash incomes, lower real interest rates, improved farmland values, and reduced agricultural debt, will continue to foster increased sales in 1989.

Demand for tractors, particularly the more powerful units, is especially strong thus far in 1989. Annual sales of over-139 horsepower (hp) two-wheel-drive and four-wheel-drive tractors are expected to be up 23 and 65 percent, respectively. Greater demand for larger hp tractors has increased the average size of new tractors purchased from 90 hp in 1986 to 95 hp in 1988.

Tillage methods affect the residue from the previous crop that remains on the soil surface. Residue coverage is beneficial in controlling erosion, a major national concern from the viewpoints of maintaining agricultural productivity and preserving water quality. Conventional tillage methods were used on nearly all of the 1988 cotton and rice acreage, and 78-88 percent of the corn, soybean, and wheat acreage. Use of no-till systems varied from less than 1 percent in cotton and rice to 7 percent in corn and Southern soybeans. Conventional tillage systems with the moldboard plow leave only 2 percent of the soil surface covered with residue after planting; conventional tillage systems without the moldboard plow leave 8 to 17 percent; and mulch-tillage systems leave nearly 40 percent.

Energy expenditures by farmers, which comprise about 5.5 percent of total farm production expenses, are projected to rise 6 percent to $7.5 billion in 1989 because of higher petroleum product prices and greater fuel use resulting from an increase in planted area for the eight major crops. Fuel use has declined over the last several years primarily because of increased use of reduced tillage practices.

Farm seed expenditures in 1989 are expected to jump 15 percent. During the 1988/89 crop marketing year, seed use for the eight major crops is expected to be 6.3 million tons, up 8 percent from the previous year due to greater planted acreage. Drought-reduced supplies and higher demand boosted most field seed prices considerably in 1989.

U.S. plant nutrient use is projected at 20.5 million tons in 1988/89 because acreage planted to corn and wheat, accounting for an estimated 58 percent of 1987/88 nutrient use, rose 8 and 17 percent. Average fertilizer prices in April rose 5 percent above the October 1988 level and 7 percent above a year earlier, primarily because of greater demand. Phosphate exports have continued strong, rising 12 percent over a year earlier, but potash exports fell by 17 percent.

Pesticide use on the 10 major field crops in 1989 is projected at 463 million pounds active ingredient, up 5 percent from 1988. Corn area, which accounted for 56 percent of herbicide and 44 percent of insecticide use in 1988, is up 5.2 million acres.

Greater pesticide demand raised average farm-level herbicide prices 5.5 percent and insecticide prices 2.9 percent between 1988 and 1989. The price of atrazine, a leading corn herbicide, jumped 18 percent. The price of methyl parathion increased 31 percent as inventories tightened in anticipation of heavy boll weevil infestations in 1989.

In 1988, most corn, soybean, and cotton herbicides were applied before or at planting. Herbicides applied before planting are generally broadcast over the entire field, while at-planting applications for corn and soybeans are divided evenly between broadcast and banded applications. For cotton, 80 percent of the at-planting applications are banded over the crop row. With a band application (10 to 13 inches wide) the active ingredient rate per acre is only one-third of the broadcast rate, reducing herbicide treatment costs.

Crop rotations, rather than continuous cropping, are often proposed to alleviate environmental and economic concerns facing the agricultural sector. With some exceptions, most crop land is involved in some type of rotation. For most States and crops, 5-10 rotations accounted for over 80 percent of the acreage planted to corn, soybeans, wheat, and rice in 1988, but in potato production rotations are more diverse.

Most crops receive more than one fertilizer application. Corn received an average of 2.2 fertilizer treatments per acre in 1988, while the average number for cotton, soybeans, and all wheat ranged from 1.2 to 1.6. Most fertilizer is applied before seeding. Twenty-three percent of the corn acreage received nitrogen in the fall, at an average rate of 100 pounds per acre.

Farm Machinery

Demand

Farm machinery expenditures in 1988 increased $250 million to $6.03 billion, despite the drought. Expenditures are expected to continue their upward trend through 1989, reaching $6.2 to $6.7 billion. Although rising since 1987, farm machinery expenditures for 1989 are still considerably lower than the 1984 level of $7.2 billion (table 1).

An increase in 1989 crop acreage strengthened farm machinery sales during the first 5 months of the year. Weather conditions weakened sales growth in 1988, but are not expected to play a significant role this year. Higher net cash income, lower real interest rates, and reductions in outstanding debt began boosting farm machinery expenditure in 1987 and will continue to increase sales through 1989. Rising farm land values are improving farmers' financial portfolio, enabling them to replace aging farm machinery.

While sales of all types of new farm machinery in 1989 will likely improve, two-wheel-drive tractors of over-139 horsepower (hp) and four-wheel-drive tractors are expected to show the greatest strength, increasing 23 and 65 percent, respectively. Combine sales should rebound 22 percent this year from the drought-induced 16-percent decline in 1988 (table 2).

More Acres Planted

Farm machinery sales in 1989 are likely being boosted in part by an increase in planted acres. An expansion in planted acres increases the return a farmer receives from the machine, because it is used on more acres. Furthermore, greater planted acreage makes machine downtime more costly because more acres must be worked within the same timeframe. Consequently, farmers have an incentive to buy machinery that they can rely on.

Acres removed from production under set-aside programs are expected to decline by over 20 million in 1989 because set-aside requirements have been reduced. Set-aside corn and wheat acres have fallen 11.3 and 13.1 million acres, respectively, from 1988. However, the number of acres entering the Conservation Reserve Program (CRP), 0/92, and 50/92 have gone up in 1989.

Net Cash Income

Net cash farm income remains an important factor strengthening farm machinery sales. Greater incomes have helped farmers reduce outstanding debt by over 25 percent since 1984. Net cash income reached a record $58 billion in 1988 and is expected to range between $50 and $55 billion this year. Though slipping from its 1988 level, net cash income in 1989 should still encourage equipment purchases.

Higher commodity prices induced by the drought and Government payments that likely exceeded $14 billion improved net cash income for 1988. More planted acres and continued strong crop prices are important in maintaining net cash income this year.

Interest Rates

Interest rates continue to add strength to farm machinery demand by maintaining the inflation-adjusted level of 1987. Though high by historical standards, the real farm machinery and equipment loan rate (table 1) is moderate relative to levels reached between 1980 and 1986. Interest rates are important even to farmers who pay cash for machinery, because they could earn interest on cash not spent.

Land Values

Farm land values continue to rise, suggesting a growing optimism about the profitability of agriculture. February 1989 U.S. farm land values showed an average nominal rise of 6 percent for the year prior, but only a 1-percent increase in real terms. Rising land values improved the equity position of farmers who own land, thus helping them finance machinery purchases.

Aging Farm Machinery Stock

Demand for farm machinery (especially new equipment) is being enhanced by an older-than-average stock. Decreased purchases of new farm machinery in the early and mid-1980's have reduced the availability of reliable used machinery. Thus, the profitability of replacing older machines has become another factor driving the increase in farm machinery demand in 1988 and 1989.

Unit Sales

Sales in all categories of new farm machinery are expected to expand in 1989. Farmers appear to be continuing a trend toward using larger tractors: sales of four-wheel-drive tractors are forecast to grow the most (65 percent), followed by a 23 percent increase in sales of over-139 hp two-wheel-drive tractors. Assuming no adverse weather conditions, combine and baler sales also are expected to show double-digit growth (22 percent) in 1989.

The sensitivity of machinery sales to weather was demonstrated by the 16-percent fall in combine sales in 1988. However, even below-average rainfall in many parts of the country did not reverse the positive growth in sales of the over-139-hp two-wheel-drive and four-wheel-drive tractors last year.

Because combines have been increasing in size, farmers need not buy as many units to replace the capacity of the present stock. Therefore, unit sales of combines are unlikely to reach the peaks of the late 1970's.

Table 1--Trends in U.S. farm investment expenditures and factors affecting farm investment demand

Item	1984	1985	1986	1987	Preliminary 1988	Forecast 1989
			Billion dollars			
Capital expenditures:						
Tractors	2.54	1.94	1.51	1.85	2.22	2.1-2.5
Other farm machinery	4.68	3.65	3.09	3.92	3.81	4.0-4.4
Total	7.22	5.59	4.61	5.77	6.03	6.2-6.7
Tractor and machinery repairs	3.8	3.7	3.7	3.9	4.0	4.0-4.5
Trucks and autos	2.0	1.8	1.7	1.9	1.7	2.0-2.4
Farm buildings 1/	3.3	2.3	2.1	2.2	2.4	2.5-2.8
Factors affecting demand:						
Interest expenses	21.1	18.7	16.9	15.5	16	15-17
Total production expenses	143	134	122	124	133	136-140
Outstanding farm debt 2/ 3/	204	188	167	153	150	149-157
Farm real estate assets 2/	694	606	554	567	599	610-620
Farm nonreal estate assets 2/ 3/	256	240	235	246	262	253-263
Agricultural exports 4/	38.0	31.2	26.3	27.9	35.3	38
Net farm income	32.0	32.3	37.5	46	41	47-52
Net cash income	38.7	46.6	51.4	57.1	58	50-55
Direct Government payments	8.4	7.7	11.8	16.7	14	10-12
			Million acres			
Diverted acres 5/	27.0	30.7	48.1	76.2	77.7	59.2
			Percent			
Real prime rate 6/ 7/	8.3	6.9	5.8	4.9	6.1	7.0
Nominal farm machinery and equipment loan rate 8/	14.6	13.7	12.2	11.5	11.7	na
Real farm machinery and equipment loan rate 7/	10.8	10.7	9.4	8.1	7.8	na
Debt-asset ratio 9/	21.5	22.2	21.4	18.8	17.4	17-18

na = Not available.

1/ Includes service buildings and structures and land improvements. 2/ Calculated using nominal dollar balance sheet data, including farm households for December 31 of each year. 3/ Excludes CCC loans. 4/ Fiscal year. 5/ Includes acres idled through commodity programs and acres enrolled in the Conservation Reserve Program. 6/ Monthly average. 7/ Deflated by the GNP Deflator. 8/ Average annual interest rate. From the quarterly sample survey of commercial banks: Agricultural Financial Databook, Board of Governors of the Federal Reserve System. 9/ Outstanding farm debt (including households) divided by the sum of farm (including households) real and nonreal estate asset values.

Table 2--Domestic farm machinery unit sales

Machinery category	Annual average 1978-80	Annual average 1981-84	1985	1986	1987	1988	Forecast 1989	Change 87-88	Change 88-89
				Units				Percent	
Tractors:									
Two-wheel-drive--									
40-99 hp	62,818	42,131	37,847	30,848	30,718	33,154	35,500	8	7
100-139 hp	38,650	17,647	7,300	5,149	5,084	4,320	4,500	-15	4
Over 139 hp	20,893	13,626	10,400	9,313	10,818	11,802	14,500	9	23
Total over 99 hp	59,543	31,273	17,700	14,462	15,902	16,122	19,000	1	18
Four-wheel drive	10,276	6,385	2,912	2,037	1,653	2,729	4,500	65	65
Grain and forage harvesting equipment:									
Self-propelled combines	29,834	16,805	8,411	7,660	7,172	5,995	7,300	-16	22
Forage harvesters 1/	11,145	5,093	2,460	2,164	2,280	2,406	2,600	6	8
Haying equipment:									
Balers 2/	17,501	9,975	7,038	5,734	5,352	5,735	7,000	7	22
Mower conditions	23,392	14,954	11,243	10,898	11,239	11,043	12,000	-2	9

1/ Shear bar type. 2/ Producing bales up to 200 pounds.

Source: Historical data are from the Farm and Industrial Equipment Institution (FIEI). All 1989 values are ERS forecasts.

Growth in Demand for High Horsepower Tractors

The 15-percent fall in 100-139 hp tractors, combined with the 9-percent growth in over-139-hp two-wheel-drive and the 65-percent jump in four-wheel-drive tractors in 1988, indicates a continued growth in the use of larger hp tractors. Demand for 100-139 hp tractors can fall or remain weak in a growing farm machinery market because they are being replaced by larger two-wheel-drive and four-wheel-drive tractors.

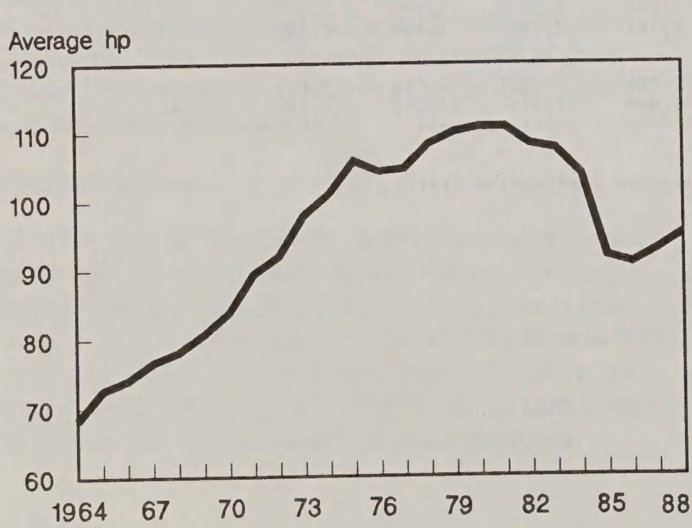
Use of larger tractors suggests a tractor replacement rate of less than one-for-one, since fewer tractors are needed to farm the same amount of land. But use of larger tractors will encourage purchases of larger tillage machinery and other associated equipment. In addition, farmers can offer custom services to help cover the purchase of the machinery.

The pattern in demand for 40-99 hp tractors resembles that of most other farm machinery. Tractors of 40-99 hp are commonly used on dairy and specialty farms, and on farms with terrain that limits field size. Also, 40-99 hp tractors are used to perform tasks around the farmstead. The diversity of uses of the 40-99 hp tractors makes demand for them more stable than for larger tractors.

The demand for the larger tractors differs from that of smaller tractors because they represent a larger investment and are used primarily for tillage. Thus, demand for larger tractors depends more closely on farmers' ability to obtain financing and on the profitability of major crops.

Sales growth in larger tractors for tillage suggests that farmers find large-scale production more cost-effective. Greater use of larger tractors represents an upgrading of equipment and an increase in the scale of farm operations. Tight financial conditions and reduced cash incomes in the 1980's likely limited efforts to expand farm size.

Figure 1
Average new tractor horsepower



The reduction in demand for large tractors in the first half of the 1980's is indicated in the reduced average size of new farm tractors sold (fig. 1). By 1986, the average size of farm tractors sold was 90 hp from a 1980 high of 110 hp. Since sales first increased in 1987, the new average tractor size has increased to 95 hp.

Inventories

Farm machinery inventories relative to sales as of May 1989 are near the 6-month level for tractors, but continue high for haying equipment (fig. 2). Strong growth in sales of large tractors has played an important role in lowering the inventory-to-sales ratio. However, the decline in combine inventories from 14,556 to 4,223 units is why the inventory-to-sales ratio fell between 1984 and 1988 (fig. 2). The high inventories of haying and harvesting equipment should not only meet farmers' needs, but also make dealers' prices more competitive.

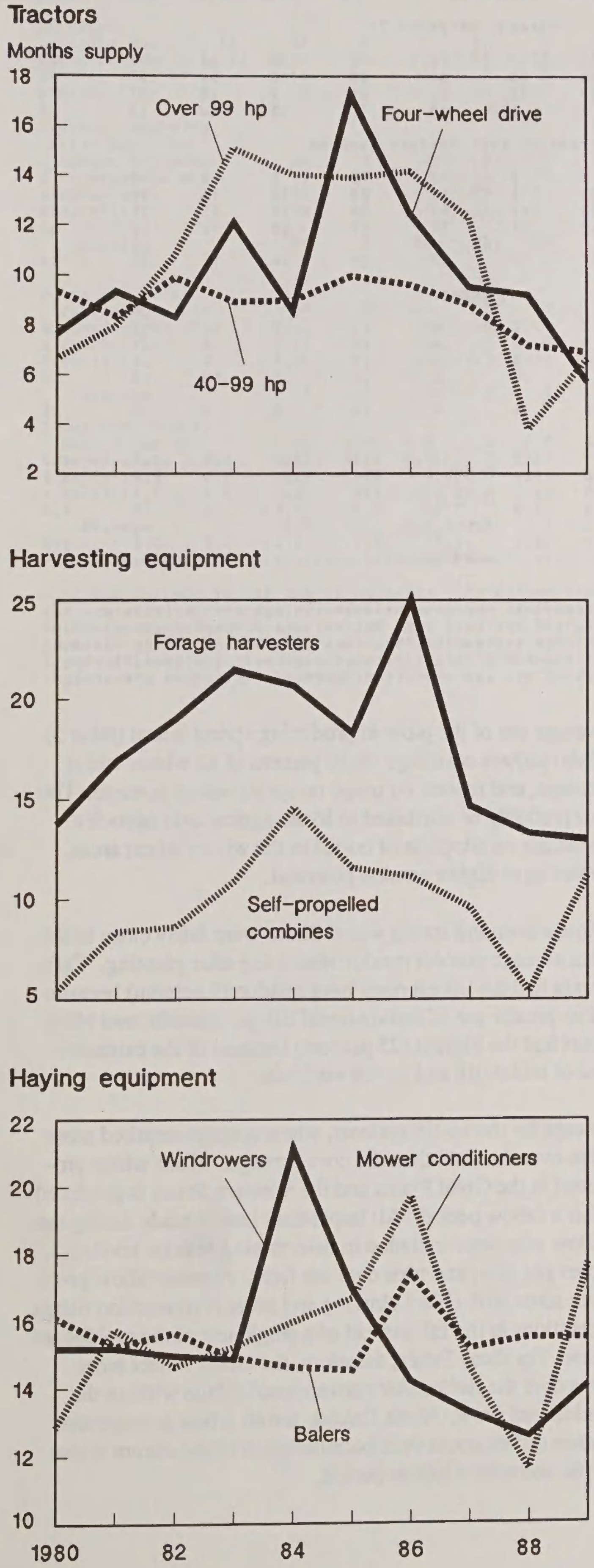
Manufacturers once desired to hold inventories at a 6-month supply. But their high inventories of the 1980's have prompted efforts to minimize machine inventories by producing only to fill an order. Under this low inventory distribution system (LIDS), manufacturers would hold little or no machine inventories. The current levels of inventories indicate that manufacturers have not extensively implemented LIDS. Unless significant savings are realized, this practice will likely be unpopular among farmers because it requires that orders be placed 6 or more months before delivery.

Tillage Practices and Residue Levels

Tillage systems and residue remaining after planting are important indicators of soil erosion potential. The conservation compliance provisions of the 1985 Food Security Act (FSA) require that highly erodible land (HEL) be protected by conservation practices by 1995 to reduce erosion to a specified level, or be ineligible for farm program benefits. The Act states that a field designated as highly erosive must have a conservation plan approved by 1990 and fully implemented by 1995. To meet requirements on erosive soils, a change in crop rotation, a change in tillage system, and/or the installation of permanent structures may be recommended. In many situations, changing tillage systems may be the cheapest alternative. Up to one-third of a field could consist of highly erosive soils, and the field would still not be designated HEL. Conservation practices applied to these non-HEL lands, even though not required by the FSA, would also improve water quality and protect erosive soils.

The type of tillage system employed also influences the types and levels of other input use. Labor and fuel inputs are reduced by tillage systems that require fewer trips over the field. Tillage systems may affect the use of herbicides and fertilizers. For example, a no-tillage system used on sod or

Figure 2
May inventory-to-purchase ratios



small grain acreage usually requires an extra herbicide application to kill the vegetation, and increased fertilizer levels are sometimes recommended.

Of the acreage planted to the major crops, currently 15 to 30 percent of the acreage is tilled with a moldboard plow; a no-tillage system is used on 7 percent or less, depending on the crop. Most of the acreage is cropped with conventional tillage without the moldboard plow. This system leaves less than 30 percent residue remaining after planting. Within these analyses, the percent of residue remaining after planting was assumed to be evenly distributed over the soil surface.

For erosion control purposes, a conservation tillage system is defined as one which leaves 30 percent or more of the soil surface covered with residue after planting. Less than 25 percent of the 1988 crop acreage surveyed would meet this criterion. This statistic may have implications for the amount of land that would currently meet conservation compliance restrictions. Producers farming HEL acres that don't currently meet these restrictions may have to change their tillage system or risk losing farm program benefits.

There is a significant difference between remaining residue levels for different tillage systems. Therefore, the type of tillage system has a direct relationship to erosion potential and water quality. In general, conventional tillage systems without the use of a moldboard plow leave less than one-half as much residue after planting as mulch-till systems. Time spent in tilling the soil is related to the number of times the farmer went over the field, as well as implement size and tractor speed. For example, under conventional tillage without a moldboard plow, times over the field varies from an average of 3.5 for corn to over 6 for cotton; hours per acre average 0.4 and 0.7, respectively. Less tillage time permits fuel and labor savings.

Tillage designations for 1988 were determined from estimates of residue remaining after planting. The percent of residue remaining (percent of soil surface covered with residue) was estimated based on the previous crop grown and the residue incorporation rates of tillage implements used.

Corn

Tillage practices used in 1988 corn production varied widely among the 10 major producing States (table 3). Use of a moldboard plow is highest in Wisconsin (57 percent) to accommodate the corn/alfalfa rotations needed to support dairy farming. In Nebraska, the moldboard plow was used on only about 5 percent of the corn acres. Nebraska does not have a preponderance of wet/heavy soils which require fall plowing. Furthermore, Nebraska has a more serious wind erosion problem than the other States. Overall, a moldboard plow was used on 20 percent of the 1988 corn acres.

Table 3--Tillage practices used in corn production, 1988

Category	IL	IN	IA	MI	MN	MO	NE 1/	NE 2/	OH	SD	WI	Area
Planted acres (1000)	9900	5200	11300	2100	5700	2200	3300	4600	3300	3150	3450	53200
						Percent of acres 3/						
Tillage:												
Conv/w mbd plow 4/	10	25	14	35	31	17	id	5	38	25	57	20
Conv/wo mbd plow 5/	72	57	66	42	44	68	61	63	40	54	35	60
Mulch-till 6/	11	8	15	11	20	10	24	21	9	18	7	14
No-till 7/	7	10	5	11	5	5	10	12	13	id	id	7
					Percent of soil surface covered							
Residue remaining after planting:												
Conv/w mbd plow	2	2	2	2	3	2	id	2	2	2	2	2
Conv/wo mbd plow	15	15	17	17	14	14	18	20	15	16	20	16
Mulch-till	37	35	38	41	38	41	41	39	37	37	35	38
No-till	57	64	57	72	42	65	65	69	68	id	id	60
Average	19	18	20	21	17	17	27	29	19	17	11	19
							Number					
Hours per acre:												
Conv/w mbd plow	.6	.7	.7	.8	.7	.9	id	.7	.9	.6	.9	.8
Conv/wo mbd plow	.4	.4	.4	.5	.5	.5	.4	.4	.5	.4	.7	.4
Mulch-till	.3	.3	.3	.4	.2	.2	.3	.4	.4	.3	.4	.3
No-till	.1	.2	.1	.2	.1	.2	.2	.2	.2	id	id	.1
Average	.4	.5	.4	.6	.5	.5	.4	.4	.6	.4	.8	.5
Times over field:												
Conv/w mbd plow	4.0	3.9	4.1	3.8	4.1	4.0	id	4.3	3.9	3.5	3.9	4.0
Conv/wo mbd plow	3.6	3.4	3.3	3.5	3.6	3.6	3.1	3.6	3.5	3.5	3.8	3.5
Mulch-till	2.7	2.9	2.4	2.6	2.5	2.3	2.4	2.6	2.8	2.8	3.1	2.6
No-till	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.3	1.0	id	id	1.0
Average	3.3	3.3	3.1	3.2	3.4	3.4	2.7	3.1	3.3	3.3	3.8	3.3

id = Insufficient data.

1/ Nonirrigated. 2/ Irrigated. 3/ May not add to 100 due to rounding. 4/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 5/ Conventional tillage without moldboard plow--any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 6/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 7/ No-tillage--No residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Among the surveyed States, no-till systems were used on only 7 percent of the corn acres. Ohio had the highest percentage (13) of acreage under no-till. Ohio has traditionally had the highest amount of no-till acreage because of the emphasis placed on such systems by its agricultural agencies.

The no-till residue remaining in Michigan and Minnesota is related to the previous crop. In Michigan, 55 percent of the corn is produced after corn and 15 percent after soybeans. In Minnesota, 31 percent is grown after corn and 46 percent after soybeans. Michigan has 72 percent average residue remaining after planting and Minnesota only 42 percent, since soybeans leave and a more sparse and fragile residue than corn. The average residue level is higher in Nebraska due to the prevalence of nonmoldboard plow tillage systems and extensive continuous corn production in this State.

Wheat

Oregon and Oklahoma report the heaviest reliance on moldboard plows in their winter wheat production (table 4). According to Extension personnel, some producers in Oregon believe that the risk of disease intensifies when large amounts of wheat residue are allowed to remain on the soil surface. Agricultural agencies in Oregon are researching this perception. Idaho and Minnesota report greater-than-average use of the plow in producing spring wheat (table 5). Idaho utilizes no-tillage on 10 percent of its winter wheat acreage, and reports no usage on spring wheat acreage. This can probably be attributed to Idaho agricultural agencies' emphasis on adoption of no-till in the winter wheat areas, which have higher erosion potential.

Most winter and spring wheat States were fairly close to the area average percent residue remaining after planting. California had the lowest remaining residue (9 percent) because of its greater use of conventional tillage methods, and Missouri had the highest (25 percent) because of the extensive use of mulch-till and no-till methods.

Except for the no-till systems, wheat acreage required more trips over the field than did corn acreage. Much wheat produced in the Great Plains and the Western States is produced after a fallow period. All implement passes made during the fallow year were included in determining residue levels, hours per acre, and trips over the field. Normal fallow procedure starts with chisel plowing and other noninversion tillage operations in the fall instead of a single use of the moldboard plow. For these States, therefore, the tables reflect more trips over the field under conventional tillage without the moldboard plow. North Dakota durum wheat acreage also shows this characteristic because much of the durum wheat is planted after a fallow period.

Table 4--Tillage practices used in winter wheat production, 1988

Category	AR	CA	CO	ID	IL	IN	KS	MO	MT	NE	OH	OK	OR	TX	WA	Area
Harvested acres (1000)	1050	440	2350	790	1220	700	9400	1550	2100	2000	920	4800	660	3100	1750	27390
	Percent of acres 1/															
Tillage:																
Conv/w mbd plow 2/	nr	6	6	16	3	13	17	id	id	19	3	29	40	nr	5	15
Conv/wo mbd plow 3/	79	86	71	66	93	78	62	68	74	68	72	64	53	77	81	67
Mulch-till 4/	16	8	24	7	5	9	20	24	17	12	18	7	6	22	12	16
No-till 5/	4	nr	nr	10	nr	nr	id	5	7	nr	7	nr	id	id	2	1
	Percent of soil surface covered															
Residue remaining after planting:																
Conv/w mbd plow	nr	1	2	2	2	3	2	id	id	2	1	2	2	nr	2	2
Conv/wo mbd plow	13	7	17	11	17	15	14	18	15	15	16	11	12	14	15	14
Mulch-till	43	43	41	45	41	45	36	41	36	36	39	38	35	39	40	38
No-till	68	nr	nr	38	nr	nr	id	68	80	nr	55	nr	id	id	35	61
Average	20	9	22	15	17	17	17	25	23	15	23	11	10	20	18	17
	Number															
Hours per acre:																
Conv/w mbd plow	nr	.6	.6	.5	.3	.9	.8	id	id	.8	1.1	.6	.6	nr	.7	.7
Conv/wo mbd plow	.3	.6	.4	.4	.4	.4	.6	.4	.4	.7	.5	.7	.5	.6	.5	.5
Mulch-till	.2	.2	.2	.3	.2	.3	.3	.3	.3	.4	.4	.6	.5	.3	.3	.4
No-till	.1	nr	nr	.1	nr	nr	id	.1	.1	nr	.2	nr	id	id	.1	.1
Average	.3	.5	.4	.4	.4	.5	.6	.4	.3	.6	.5	.6	.5	.5	.4	.5
Times over field:																
Conv/w mbd plow	nr	4.0	4.8	4.6	4.0	3.8	5.4	id	id	5.3	5.2	5.3	5.1	nr	4.6	5.3
Conv/wo mbd plow	3.3	4.7	5.4	3.7	2.7	2.6	5.3	2.7	4.8	5.4	2.6	5.2	5.1	4.8	5.7	5.0
Mulch-till	2.4	2.7	4.4	2.2	2.0	2.0	4.9	2.3	3.9	3.4	2.1	4.7	4.2	4.2	3.8	4.5
No-till	1.0	nr	nr	1.0	nr	nr	id	1.0	1.0	nr	1.0	nr	id	id	1.0	1.0
Average	3.1	4.5	5.2	3.4	2.7	2.7	5.2	2.6	4.3	5.2	2.5	5.2	5.0	4.6	5.3	4.9

id = Insufficient data. nr = None reported.

1/ May not add to 100 due to rounding. 2/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 3/ Conventional tillage without moldboard plow--any tillage system that has less than 30% remaining residue and does not use a moldboard plow.
4/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system.
5/ No-tillage--No residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Table 5--Tillage practices used in spring and durum wheat production, 1988

Category	Spring wheat ID	MN	MT	ND	SD	Area	Durum wheat ND
Harvested acres (1000)	380	2000	1500	4600	1300	9780	2500
				Percent 1/			
Tillage:							
Conv/w mbd plow 2/	28	25	nr	16	14	16	5
Conv/wo mbd plow 3/	61	61	67	62	51	62	69
Mulch-till 4/	11	13	32	22	22	21	24
No-till 5/	nr	id	id	nr	13	1	2
Residue remaining after planting:				Percent of soil surface covered			
Conv/w mbd plow	2	2	nr	2	3	2	3
Conv/wo mbd plow	6	9	17	12	16	12	14
Mulch-till	40	46	34	39	41	39	39
No-till	nr	id	id	nr	64	63	72
Average	9	12	23	17	26	17	21
				Number			
Hours per acre:							
Conv/w mbd plow	.8	.7	nr	.4	.3	.5	.3
Conv/wo mbd plow	.4	.3	.3	.4	.4	.4	.4
Mulch-till	.3	.3	.3	.3	.3	.3	.2
No-till	nr	id	id	nr	.1	.1	.1
Average	.5	.4	.3	.4	.3	.4	.3
Times over field:							
Conv/w mbd plow	3.8	5.4	nr	4.7	2.4	4.7	3.0
Conv/wo mbd plow	3.4	4.2	4.6	4.5	3.9	4.4	5.2
Mulch-till	2.5	2.6	4.2	2.9	2.2	3.1	2.9
No-till	nr	id	id	nr	1.0	1.0	1.0
Average	3.4	4.2	4.4	4.2	3.0	4.1	4.5

id = Insufficient data. nr = None reported.

1/ May not add to 100 due to rounding. 2/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting.
3/ Conventional tillage without moldboard plow--any tillage system that has less than 30% remaining residue and does not use a moldboard plow.
4/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 5/ No-tillage--No residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Soybeans

The 14 major soybean States were divided into the Northern and Southern producing areas. The Northern area reported 28 percent of the acres using conventional tillage with a moldboard plow, compared with only 3 percent of the Southern area (tables 6 and 7). In contrast, 85 percent of Southern area acreage used conventional tillage without the moldboard plow, compared with 55 percent of the Northern area. Mulch tillage was more predominant in the Northern area (14 vs. 5 percent), while no-tillage was more prevalent in the Southern area (7 vs. 3 percent). Examination of rotation data shows a distinct pattern. In the Southern area, 50-90 percent of the previous crop consisted of soybeans or a fallow period (leaving fragile and limited residues). In the Northern area, over 60 percent of the previous crop residue was corn, which leaves a nonfragile and heavier residue. Like Ohio, Kentucky is recognized as a leader in the adoption of no-till systems.

The residue remaining under conventional tillage without the moldboard plow was higher in the Northern area; for no-tillage, the residue was higher in the Southern area. The hours per acre averaged 0.7 in the Northern area and 1.1 in the Southern area for conventional tillage with the moldboard plow, even though the times over the field were nearly the same. This indicates larger implement size and/or greater tractor speed in the Northern area. The other tillage types had very similar operation times in the Northern and Southern producing areas.

Table 6--Tillage practices used in northern soybean production, 1988

Category	IL	IN	IA	MN	MO	NE	OH	Area
Planted acres (1000)	8800	4300	7950	4900	4300	2400	3900	36550
				Percent of acres 1/				
Tillage:								
Conv/w mbd plow 2/	25	28	25	54	10	9	43	28
Conv/wo mbd plow 3/	57	56	58	28	74	54	45	55
Mulch-till 4/	15	10	15	13	13	35	3	14
No-till 5/	2	6	2	6	2	id	9	3
				Percent of soil surface covered				
Residue remaining after planting:								
Conv/w mbd plow	3	3	2	2	2	3	2	2
Conv/wo mbd plow	17	16	19	15	14	20	14	17
Mulch-till	40	41	39	41	36	39	41	39
No-till	72	68	56	58	59	id	68	65
Average	18	18	18	14	16	26	14	17
				Number				
Hours per acre:								
Conv/w mbd plow	.6	.6	.7	.6	.7	.7	.8	.7
Conv/wo mbd plow	.5	.5	.5	.6	.4	.5	.5	.5
Mulch-till	.4	.4	.3	.3	.4	.3	.5	.3
No-till	.1	.2	.1	.1	.2	id	.2	.1
Average	.5	.5	.5	.5	.5	.4	.6	.5
Times over field:								
Conv/w mbd plow	4.1	3.9	4.4	4.4	4.2	4.0	4.0	4.2
Conv/wo mbd plow	4.2	3.7	4.1	4.8	3.8	3.6	3.6	4.0
Mulch-till	3.1	2.7	3.0	3.3	3.3	2.8	3.2	3.1
No-till	1.0	1.0	1.0	1.0	1.0	id	1.0	1.0
Average	3.9	3.5	3.9	4.2	3.7	3.3	3.6	3.8

id = Insufficient data.

1/ May not add to 100 due to rounding. 2/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 3/ Conventional tillage without moldboard plow--any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 4/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 5/ No-tillage--No residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Table 7--Tillage practices used in southern soybean production, 1988

Category	AR	GA	KY	LA	MS	NC	TN	Area
Planted acres (1000)	3250	900	980	1800	2400	1470	1400	12200
				Percent of acres 1/				
Tillage:								
Conv/w mbd plow 2/	id	9	7	nr	nr	13	4	3
Conv/wo mbd plow 3/	92	78	51	98	94	60	76	85
Mulch-till 4/	5	11	12	id	5	3	5	5
No-till 5/	2	id	30	nr	id	24	14	7
Residue remaining after planting:				Percent of soil surface covered				
Conv/w mbd plow	id	1	2	nr	nr	1	2	2
Conv/wo mbd plow	6	10	14	6	7	10	10	8
Mulch-till	41	34	34	id	35	41	53	40
No-till	75	id	75	nr	id	72	68	72
Average	10	13	34	7	9	25	20	14
				Number				
Hours per acre:								
Conv/w mbd plow	id	1.6	1.4	nr	nr	1.1	.7	1.1
Conv/wo mbd plow	.5	.5	.6	.5	.5	.7	.6	.5
Mulch-till	.4	.3	.3	id	.4	.5	.3	.4
No-till	.1	id	.2	nr	id	.2	.1	.2
Average	.5	.5	.5	.5	.5	.6	.5	.5
Times over field:								
Conv/w mbd plow	id	4.1	4.5	nr	nr	3.9	3.7	4.1
Conv/wo mbd plow	5.0	3.2	3.6	4.8	4.8	3.9	4.5	4.6
Mulch-till	2.5	2.8	2.9	id	3.8	2.3	2.6	2.8
No-till	1.0	id	1.0	nr	id	1.0	1.0	1.0
Average	4.8	3.2	2.8	4.7	4.7	3.1	3.9	4.3

id = Insufficient data. nr = None reported.

1/ May not add to 100 due to rounding. 2/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting.
3/ Conventional tillage without moldboard plow--any tillage system that has less than 30% remaining residue and does not use a moldboard plow.
4/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 5/ No-tillage--No residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Table 8--Tillage practices used in cotton production, 1988

Category	AZ	AR	CA	LA	MS	TX	Area
Planted acres (1000)	340	680	1350	700	1230	5400	9700
	Percent of acres 1/						
Tillage:							
Conv/w mbd plow 2/	66	7	5	id	2	33	28
Conv/wo mbd plow 3/	33	93	95	99	98	67	72
Mulch-till 4/	nr	nr	nr	nr	nr	id	id
No-till 5/	id	nr	nr	nr	nr	nr	id
Residue remaining after planting:	Percent of soil surface covered						
Conv/w mbd plow	0	0	.4	id	0	.2	.2
Conv/wo mbd plow	.6	1.0	1.5	2.7	1.8	3.3	2.9
Mulch-till	nr	nr	nr	nr	nr	id	id
No-till	id	nr	nr	nr	nr	nr	id
Average	.3	1.0	1.4	2.7	1.8	2.4	2.2
	Number						
Hours per acre:							
Conv/w mbd plow	1.5	.8	1.3	id	.8	.8	.8
Conv/wo mbd plow	1.2	.8	1.3	.7	.8	.6	.7
Mulch-till	nr	nr	nr	nr	nr	id	id
No-till	id	nr	nr	nr	nr	nr	id
Average	1.3	.8	1.3	.7	.8	.7	.8
Times over field:							
Conv/w mbd plow	7.6	6.8	6.5	id	6.0	6.1	6.2
Conv/wo mbd plow	7.5	6.2	7.2	6.0	6.7	5.9	6.1
Mulch-till	nr	nr	nr	nr	nr	id	id
No-till	id	nr	nr	nr	nr	nr	id
Average	7.5	6.3	7.2	5.9	6.7	5.9	6.1

id = Insufficient data. nr = None reported.

1/ May not add to 100 due to rounding. 2/ Conventional tillage with moldboard plow--any tillage system that includesthe use of a moldboard plow and has less than 30% residue remaining after planting. 3/ Conventional tillage without moldboard plow--any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 4/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 5/ No-tillage--No residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

Cotton

Nearly all cotton is produced using conventional tillage methods in the six major cotton producing States (table 8). Use of the moldboard plow was quite minimal in four of these States. The plow was used most extensively in Arizona (66 percent) and Texas (33 percent). Arizona and California have State "plow-down" laws requiring that the cotton plant be disposed of to eliminate the food source for bollworms and boll weevils. Many producers have interpreted these laws to mean that the previous crop must be plowed under or receive multiple diskings and other tillage. California producers mainly use multiple diskings with a heavy disk. Arizona agricultural agencies currently advocate a reduction in the number of tillage operations, decreased use of the moldboard plow, and increased use of cover crops. These recommendations, which meet the legal requirements, are aimed at cutting input cost and preserving organic matter. Certain areas of Texas also have a "plow-down" law, and in some areas the moldboard plow is also used to bring up subsoil clay material to cover the surface with clods, which helps control wind erosion.

Table 9--Tillage practices used in rice production, 1988

Category	AR	CA	LA	Area
Planted acres (1000)	1180	425	525	2130
	Percent of acres 1/			
Tillage:				
Conv/w mbd plow 2/	id	10	nr	2
Conv/wo mbd plow 3/	97	90	95	96
Mulch-till 4/	2	id	5	2
No-till 5/	id	nr	id	id
Residue remaining after planting:	Percent of soil surface covered			
Conv/w mbd plow	id	0	nr	0
Conv/wo mbd plow	2	2	4	2
Mulch-till	43	id	36	41
No-till	id	nr	id	id
Average	4	2	6	4
	Number			
Hours per acre:				
Conv/w mbd plow	id	id	nr	id
Conv/wo mbd plow	.7	.4	.6	.6
Mulch-till	.3	id	id	.3
No-till	id	nr	id	id
Average	.6	.4	.6	.6
Times over field:				
Conv/w mbd plow	id	id	nr	id
Conv/wo mbd plow	6.0	7.3	5.0	6.0
Mulch-till	3.5	id	id	3.5
No-till	id	nr	id	id
Average	5.9	7.4	4.9	6.0

id = Insufficient data. nr = None reported.

1/ May not add to 100 due to rounding. 2/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30% residue remaining after planting. 3/ Conventional tillage without moldboard plow--any tillage system that has less than 30% remaining residue and does not use a moldboard plow. 4/ Mulch-tillage--System that has 30% or greater remaining residue after planting and is not a no-till system. 5/ No-tillage--No residue-incorporating tillage operations performed prior to planting, allows passes of nontillage implements, such as stalk choppers.

The significant number of tillage trips across the field (averaging 6.1) leaves very little residue, even without use of the moldboard plow. Research and testing is being conducted on mulch-till and no-till systems, cover crops, and the number of tillage trips in a number of cotton producing States.

Rice

The majority of rice acreage in Arkansas, California, and Louisiana is produced under conventional tillage without the moldboard plow (table 9). Erosion is not a problem in rice production because most rice is produced on flat, heavy-textured soils and then flooded. Most rice is planted on a nearly residue-free seedbed, partly because residue is perceived to harbor the disease organism that causes stem rot at the water line. A small amount of rice acreage is produced with mulch tillage in Arkansas (2 percent) and Louisiana (5 percent). Most of the acreage in these two States had a previous crop of soybeans or a fallow period, leaving fragile, light residues.

Energy

U.S. farmers can expect 1989 energy prices to remain above 1988 levels due to higher crude oil prices in recent months. In contrast, farm fuel prices rose slightly in 1988. Energy expenditures by farmers (which comprise about 5.5 percent of total farm production expenses) are projected to increase 6 percent to $7.5 billion because of higher petroleum product prices and greater fuel use resulting from an increase in planted area for eight major crops (except cotton and rice).

Oil Consumption and Production

Organization of Petroleum Exporting Countries's (OPEC) June 1989 agreement called for a price target of $18 per barrel and an increase of its output target from the current 18.5 to 19.5 million barrels per day for the next few months. OPEC's current output is estimated at 21 million barrels per day. Total world consumption of petroleum for 1988 increased 2.8 percent to 50.1 million barrels per day, the highest level since 1979. World consumption is expected to edge up slightly in 1989.

Preliminary Department of Energy (DOE) forecasts indicate that economic growth of about 2.6 percent will offset higher crude oil prices, and U.S. petroleum consumption will therefore increase 0.9 percent in 1989 (table 10). For the first time since 1980, domestic petroleum demand averaged over 17 million barrels per day, and is expected to remain above that level in 1989. U.S. refiners paid an average of $16.50 per barrel in the first quarter of 1989, about 25 percent more than they did in the last quarter of 1988. Prices began surging near the end of 1988, and West Texas Intermediate crude exceeded $20 per barrel in June 1989 (fig. 3). World oil demand has stabilized somewhat in the first half of the year,

reflecting steady but slow economic growth in major oil consuming countries. Crude oil prices are expected to range from $15 to $20 per barrel in 1989.

Domestic production of crude oil probably will fall for the fourth consecutive year in 1989, declining 200,000 barrels per day. Despite higher crude oil prices, incentives to U.S. producers remain insufficient to cover production expenses

Table 10--U.S. petroleum consumption-supply balance

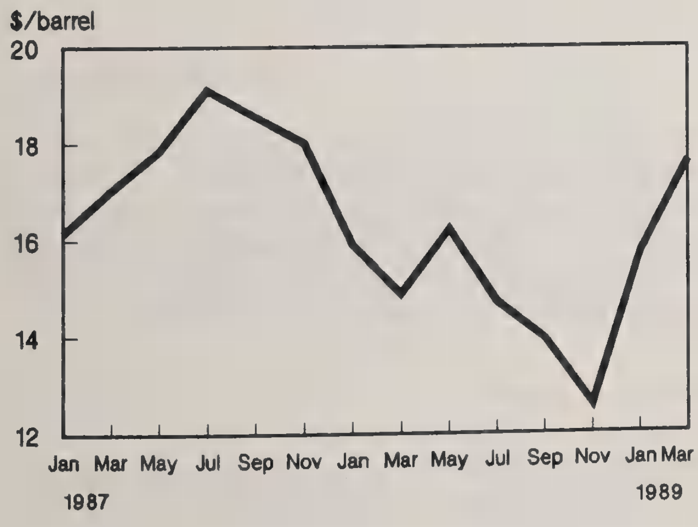
Item	1986	1987	1988	Forecast 1989
		Million barrels per day		
Consumption:				
Motor gasoline	7.03	7.21	7.31	7.41
Distillate fuel	2.91	2.98	3.10	3.14
Residual fuel	1.42	1.26	1.33	1.25
Other petroleum 1/	4.92	5.22	5.43	5.52
Total	16.28	16.67	17.17	17.32
Supply:				
Production 2/	10.96	10.68	10.51	10.25
Net imports (excludes SPR)	5.38	5.84	6.37	7.03
Net stock withdrawals	-0.21	0.05	0.35	0.04
Total	16.28	16.67	17.17	17.32
		Percent		
Net imports as a share of total supply	33	35	37	41
		Percent change from previous year		
Consumption		2.4	3.0	0.9
Production		-2.6	-1.6	-2.5
Imports		8.6	8.7	10.4

SPR = Strategic Petroleum Reserve, October 1988 projections.

1/ Includes crude oil product supplied, natural gas liquid (NGL), other hydrocarbons and alcohol, and jet fuel. 2/ Includes domestic oil production, NGL, and other petroleum products.

Source: U.S. Department of Energy. Energy Information Administration. Short-Term Energy Outlook, DOE/EIA-0202 (88/4Q). May 1989.

Figure 3
World oil prices



in many high-cost U.S. fields. The projected output of 7.8 million barrels per day in 1989 will be the lowest domestic production in 25 years. Expanding demand and decreasing domestic production are expected to boost U.S. net imports by 10.4 percent in 1989 to 7.0 million barrels per day, or 41 percent of domestic consumption. The 1989 import estimate may be compared with the record high import of 8.6 million barrels per day in 1977 (47 percent of consumption), and the low of 4.3 in 1985 (only 27 percent of consumption).

Energy In the Farm Sector

The energy supply and price outlook for U.S. agriculture largely reflects world market conditions, currently characterized by abundant oil supplies priced above 1988 levels. In 1989, farmers can expect plentiful supplies of diesel fuel, gasoline, and liquified petroleum (LP) gas, but at slightly higher prices than last year.

Farm Fuel Use

Combined gasoline and diesel fuel use has fallen in recent years due to adoption of energy-saving farm production technologies, shifts from gasoline to more fuel-efficient diesel-powered units, and generally reduced planted area (table 11). Although the number of acres planted influences the fluctuations in farm energy use, other factors also have contributed to the decline. Continued replacement of older gasoline machines by efficient diesel-powered machines, particularly in the production of cotton, rice, and some minor crops, has resulted in more use of diesel fuel than gasoline since 1980. (USDA data suggest that this machinery switch was largely complete in the 1970's for corn, wheat, and soybeans).

In 1988 on-farm diesel fuel use declined about 3 percent due to the drought, while gasoline and LP use remained unchanged. With a return to normal weather and an increase in planted acreage, diesel fuel use is projected to increase 14

Table 11--Farm fuel use

Year	Gasoline	Diesel	LP gas
		Billion gallons	
1979	3.4	3.2	1.1
1980	3.0	3.2	1.1
1981	2.7	3.1	1.0
1982	2.4	2.9	1.1
1983	2.3	3.0	0.9
1984	2.1	3.0	0.9
1985	1.9	2.9	0.9
1986	1.7	2.9	0.7
1987	1.5	3.0	0.6
1988	1.6	2.8	0.6
1989 1/	1.6	3.2	0.6

1/ Projected.

Table 12--Fuel efficiency of diesel tractors tested at the University of Nebraska

Horsepower class 1/	Before 1950	1950-59	1960-69	1970-74	1975-79	1980-84
			Fuel efficiency 2/			
LT30	11.5	13.1	16.0	16.0	15.3	14.5
30-39	16.0	15.3	15.7	16.3	16.4	15.1
40-49	15.4	15.9	15.5	16.3	16.0	15.8
50-59	15.3	16.1	15.9	16.2	16.0	16.1
60-69	16.0	15.6	15.3	16.0	16.3	16.3
70-79	15.0	16.2	16.0	15.2	16.0	16.2
80-89	16.0	14.5	16.0	15.8	16.1	16.1
90-99	13.7	15.3	16.0	15.6	16.0	16.2
100-119	16.0	16.0	16.0	16.0	14.3	16.1
120-129	13.5	14.0	16.2	16.3	16.0	16.3
130-139	16.0	16.0	16.0	16.0	16.0	16.0
140-149	-	-	17.0	16.0	16.2	16.4
150-159	-	-	-	16.0	16.0	16.0
160-169	-	-	-	16.0	16.0	16.5
170-179	-	-	-	16.0	16.0	16.2
180-199	-	-	-	16.0	16.0	16.3
200+	-	-	-	16.0	16.0	16.5
			Number tested			
LT30	2	4	5	3	15	23
30-39	5	26	28	3	5	8
40-49	14	23	19	7	12	21
50-59	4	17	28	6	9	15
60-69	6	9	21	9	10	18
70-79	7	6	11	8	4	16
80-89	2	2	6	11	11	15
90-99	4	4	11	8	3	9
100-119	5	2	17	15	17	15
120-129	2	2	6	8	6	8
130-139	1	1	4	9	7	4
140-149	-	-	1	9	5	5
150-159	-	-	-	5	4	3
160-169	-	-	-	1	7	8
170-179	-	-	-	3	3	5
180-199	-	-	-	1	11	7
200+	-	-	-	1	9	13

- = None tested.

1/ Maximum brake horsepower. 2/ Hp-hr/gal measured at maximum hp at rated RPM.

Source: Wendell, C.H. "Nebraska Tractor Tests Since 1920," Crestline Publishing Co., Sarasota, FL, 1985.

percent, while gasoline and LP use is projected to remain flat (table 11).

Over the last 40 years, gains in the fuel efficiency of gasoline and diesel tractors have been quite modest and limited primarily to the larger diesel tractors (tables 12 and 13). Although gasoline tractors have shown small fuel efficiency gains over time, it appears that diesel tractors reached maximum fuel efficiency as early as the 1960's, particularly for the larger horsepower classes. Consequently, fuel use has declined primarily because of reduced tillage practices, not because of tractor fuel efficiency gains.

The testing of diesel tractors increased in the 1980's while that of gasoline tractors had ceased. The last gasoline-powered farm tractors were manufactured in the United States in 1984, and most production stopped before 1980. Before 1950, 180 gasoline tractors were tested compared to 52 diesel tractors. In contrast, after 1970, 438 diesel tractors were tested, compared to only 38 gasoline tractors.

Energy Expenditures Up in 1989

In 1989 farm energy (gasoline, diesel fuel, LP gas, and electricity) expenditures are projected to reach an estimated $7.5 billion, up about 6 percent over 1988 (table 14). This reflects an 11-percent increase in fuel expenditures and flat electricity expenditures. This gain is largely due to a 16-mil-

Table 13--Fuel efficiency of gasoline tractors tested at the University of Nebraska

Horsepower class 1/	Before 1930	1930-39	1940-49	1950-59	1960-69	1970-74	1975-79	1980-84
				Fuel efficiency 2/				
LT30	8.1	8.7	-	10.5	-	11.0	11.0	9.0
30-39	-	9.4	-	10.8	11.3	11.3	11.0	-
40-49	-	10.3	11.3	11.1	11.8	10.7	11.3	-
50-59	-	-	10.6	11.5	11.3	10.7	12.0	-
60-69	-	-	10.2	11.4	11.3	10.3	-	-
70-79	-	-	11.0	-	11.6	10.3	-	-
80-89	-	-	10.0	11.0	11.5	11.3	11.3	-
90-99	-	-	11.0	-	11.0	-	-	-
100-119	-	-	10.5	-	-	-	-	-
			Number tested					
LT30	55	15	-	25	-	1	1	1
30-39	-	52	-	38	23	4	3	-
40-49	-	7	19	29	13	3	4	-
50-59	-	-	12	15	21	3	1	-
60-69	-	-	12	7	19	3	-	-
70-79	-	-	2	-	8	4	-	-
80-89	-	-	2	1	6	4	6	-
90-99	-	-	2	-	9	-	-	-
100-119	-	-	2	-	-	-	-	-

- = None tested.

1/ Maximum brake horsepower. 2/ Hp-hr/gal measured at maximum hp at rated RPM.

Source: Wendell. C.H., "Nebraska Tractor Tests Since 1920," Crestline Publishing Co., Sarasota, Fla., 1985.

Table 14--Farm energy expenditures

	1986	1987	Prelim-inary 1988	Forcast 1989
			Billion dollars	
Fuels and oil	4.8	4.4	4.4	5.0
Electricity	2.1	2.4	2.5	2.5
Total	6.9	6.8	7.1	7.5
Percent change from preceding year		-1	4	6

Source: U.S. Department of Agriculture. National Agricultural Statistics Service. Farm Production Expenditures, selected issues. Washington, D.C.

Table 15--Average U.S. farm fuel prices 1/

Year	Gasoline	Diesel	LP gas
	Dollar per gallon 2/		
1980	1.15	0.99	0.62
1981	1.29	1.16	0.70
1982	1.23	1.11	0.71
1983	1.18	1.00	0.77
1984	1.16	1.00	0.76
1985	1.15	0.97	0.73
1986	0.89	0.69	0.67
1987	0.92	0.71	0.59
1988	0.93	0.73	0.59
1989			
January	0.92	0.71	0.59
April	1.07	0.80	0.58
July	1.13	0.74	0.58

1/ Derived from surveys of farm supply dealers conducted by the National Agri-cultural Statistics Service, USDA. 2/ Bulk delivered.

lion-acre increase in planted acreage, offsetting long-term reductions in fuel use related to conservation.

Energy Prices Rise in 1989

In response to higher world oil prices, farm fuel prices are projected to rise in 1989. In April, the average price of bulk-delivered regular leaded gasoline was $1.07 per gallon, an increase of 13 cents per gallon from January (table 15). The April energy price index showed an 11-percent increase over January and a 12-percent rise over a year earlier. Prices could moderate late in the year given flat crude oil prices.

Seeds

Consumption

In the 1988/89 crop marketing year, seed use for the eight major crops is expected to reach 6.3 million tons, up 8 percent over the previous year, primarily due to an increase in planted acres of wheat, corn, and soybeans (table 16). However, 1988/89 seed use is still lower than that of 1980/81, when 7.2 million tons were consumed due to record planted acreage.

Prices

As expected, higher demand and lower supply appreciably boosted most field seed prices paid by farmers in 1989. Prices for seed potatoes, oat, barley, soybean, wheat, corn, and grain sorghum seeds jumped 49, 35, 29, 24, 14, 11, and 6 percent, respectively, from 1988 (table 17). Factors responsible for higher seed prices, particularly corn and soybeans, are: the 1988 drought-reduced seed supply; expensive off-season seed production; and greater planted acreage. Soybean, wheat, oat, seed potato, and barley seed prices tend to follow commercial crop prices, which have climbed substantially since the beginning of 1988. Prices received by farmers for these commodities jumped 12, 44, 28, 95, and 73 percent, respectively, between April 1988 and April 1989. Despite a 16-percent decline in cotton acreage, seed prices rose 5 percent.

Forage seed prices, particularly grass, have increased over the last 3 years due to expanded demand because of the CRP. An additional 2.5 million acres have been enrolled so far in 1989. As of June, 1989 total CRP contracted area had risen to 30.6 million acres.

Although timothy and orchardgrass prices have stabilized, they remain much higher than in 1985, when the CRP was enacted. Fescue and ryegrass prices have risen sharply—55 and 13 percent, respectively, from year-earlier levels. Although fescue prices have gone up sharply since 1988, they exceed 1987 levels by only 4 percent. Alfalfa prices rose only 2 percent in 1989, whereas lespedeza (sericea) prices fell 39 percent due to increased supplies in 1988. USDA's prices paid index for seed climbed to 170, up 13 percent over April 1988.

Seed Expenditures

In 1988, total farm seed expenditures rose 4 percent from 1987 to $3.69 billion (table 18). Seed expenditures reflect higher seed prices and greater planted acreage in 1988 compared with 1987. Farm seed expenditures may rise 15 percent in 1989 due to substantially higher field seed prices and further increases in planted acreage.

U.S. Seed Exports and Imports

Corn Seed Exports

The decline in domestically produced field corn seed, engendered by the severe drought of 1988, has reduced exports to

Table 16--Seed use for U.S. major field crops 1/

Crops	1985/86	1986/87	1987/88	1988/89 2/	Change 87/88-88/89
		1,000 tons			Percent
Corn	546	468	482	519	8
Sorghum	48	45	39	43	10
Soybean	1,770	1,653	1,684	1,766	5
Barley	514	430	377	362	-4
Oats	614	450	467	406	-13
Wheat	2,790	2,520	2,550	2,984	17
Rice	130	130	150	142	-5
Cotton	92	93	106	89	-16
Total	6,504	5,789	5,855	6,311	8

1/ Crop marketing year. 2/ Based on June 1, 1989 planted acreage.

Table 17--Prices paid by farmers for selected planting seeds 1/

Item	Unit	1987	1988	1989	Change 88-89
					Percent
Field seeds:					
Corn	2/	64.90	64.20	71.40	11
Grain sorghum	$/cwt.	63.60	65.70	69.50	6
Oats	$/bu.	3.99	4.37	5.89	35
Barley	$/bu.	4.47	4.58	5.91	29
Wheat (spring)	$/bu.	5.56	5.89	6.71	14
Wheat (winter)	$/bu.	3/	6.57	7.55	15
Soybeans	$/bu.	11.30	11.90	14.70	24
Cotton	$/cwt.	48.10	47.70	50.10	5
Potatoes	$/cwt.	7.95	7.12	10.60	49
Forage seeds:					
Red clover	$/cwt.	160.00	143.00	143.00	0
Fescue 4/	$/cwt.	107.00	71.80	111.00	55
Orchardgrass	$/cwt.	115.00	116.00	117.00	1
Ryegrass, annual	$/cwt.	45.10	47.90	54.30	13
Timothy	$/cwt.	107.00	132.00	132.00	0
Lespedeza, sericea	$/cwt.	233.00	278.00	167.00	-40
Alfalfa, proprietry	$/cwt.	222.00	245.00	249.00	2
Seed price paid index (1977=100)		148	150	170	13

1/ Derived from the April survey of farm supply dealers conducted by the National Agricultural Statistics Service, USDA. 2/ $/80,000 kernels. 3/ Not available. 4/ Tall, Alta, and Kentucky 31.

Table 18--U.S.farm expenditures for seeds 1/

Item	1985	1986	1987	1988	Change 87-88
	Billion dollars				Percent
Field crops and small grains	3.17	2.70	2.45	2.49	2
Legumes, grasses, and forages	0.37	0.39	0.39	0.33	-13
Seeds and plants for other crops	0.36	0.37	0.65	0.78	20
Other seed expenses 2/	0.04	0.04	0.05	0.09	80
Total seed expenditures	3.94	3.50	3.54	3.69	4

1/ Excludes bedding plants, nursery stocks, and seed purchased for resale. 2/ Includes seed treatment.

the major importing countries. Exports by volume to the Netherlands, Japan, Spain, France, Italy, and Greece declined 74, 51, 40, 20, 18, and 14 percent, respectively, in the first quarter of 1989 compared with the corresponding period of 1988 (table 19). U.S. field corn seed exports by volume equaled 12,400 metric tons in the first quarter of 1989—8 percent lower than in the corresponding period a year earlier.

However, corn seed exports to Mexico, Turkey, and Japan increased in the first quarter of 1989. The volume exported to Mexico jumped from 534 metric tons in the first quarter of 1988 to 2,927 metric tons in 1989. Mexico also experienced severe drought in 1988, sharply reducing its corn seed production, and imported large quantities to meet domestic demand.

Corn Seed Imports

U.S. corn seed imports increased sharply to supplement the 1988 drought-reduced domestic supply. Between the first quarter of 1988 and 1989, total corn seed imports rose from 2,970 metric tons to 11,739 metric tons, a jump of 295 percent. Canada has traditionally been the largest supplier of corn seed to the United States, while Argentina, Chile, and Hungary have exported widely varying quantities. During the first quarter of 1989, imports from Canada rose 94 percent by volume (table 20). Several companies grew corn

Table 19--U.S. seed corn exports by volume

Country	1986	1987	1988	January-March 1988	January-March 1989	Change 88-89
	Metric tons					Percent
Canada	1,621	2,505	2,582	1,617	796	-51
Mexico	3,703	3,143	3,151	534	2,927	448
Chile	64	166	541	0	0	0
Argentina	867	699	808	24	0	-100
France	2,121	2,542	2,439	917	733	-20
Spain	1,245	2,049	4,134	2,173	1,313	-40
Italy	7,939	12,229	8,741	3,164	2,586	-18
Netherlands	5,127	695	1,060	271	71	-74
Greece	3,088	1,894	2,251	2,044	1,759	-14
Turkey	3,224	2,678	1,104	51	239	368
Japan	720	1,861	1,322	623	660	6
Subtotal	29,719	30,461	28,133	11,418	11,084	-3
Total export	44,662	32,412	33,547	13,361	12,353	-8

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Table 20--U.S. corn seed imports by volume

Country	1986	1987	1988	January-March 1988	January-March 1989	Change 88-89
	Metric tons					Percent
Canada	8,102	4,465	3,988	1,828	3,554	94
Argentina	71	0	0	0	1,593	na
Chile	14	67	2,055	995	1,278	28
Hungary	271	196	1,327	35	3,708	10,494
Subtotal	8,458	4,728	7,370	2,858	10,133	255
Total import	8,500	4,754	7,909	2,970	11,739	295

na = Not applicable.

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Table 21--U.S. soybean seed exports by volume

Country	1986	1987	1988	January-March 1988	January-March 1989	Change 88-89
	Metric tons					Percent
Canada	1,510	6,087	292	94	88	-6
Mexico	1,515	12,630	8,922	0	38,418	na
France	2,073	1,404	2,147	1,714	962	-44
Italy	22,522	44,348	26,728	12,673	13,690	8
Turkey	5,879	5,038	3,798	257	810	215
South Korea	2	0	2,000	1,000	0	-100
Japan	2,934	4,151	5,277	1,293	126	-90
Subtotal	36,435	73,658	49,164	17,031	54,094	218
Total export	37,317	75,164	52,536	17,597	54,836	212

na = Not applicable.

Source: Department of Commerce, Bureau of the Census, Foreign Trade Division.

Table 22--U.S. forage seed exports by volume

Country	1986	1987	1988	January-March 1988	January-March 1989	Change 88-89
	Metric tons					Percent
Canada	4,938	8,513	9,758	4,201	3,302	-21
Mexico	5,200	5,749	6,964	1,363	1,303	-4
Argentina	1,834	1,657	2,154	1,098	583	-47
UK	1,508	1,559	1,846	897	628	-30
Netherlands	2,644	1,865	1,870	632	529	-16
France	1,202	1,194	750	587	883	50
West Germany	1,042	561	721	292	311	7
Italy	3,945	3,788	3,249	806	808	0
Saudi Arabia	20,613	1,752	1,531	467	998	114
South Africa	1,173	1,187	657	122	222	82
South Korea	2,500	1,893	1,555	686	649	-5
Japan	9,383	11,816	10,772	3,476	3,653	5
Australia	1,880	3,419	3,316	1,455	959	-34
Subtotal	57,862	44,953	45,143	16,082	14,828	-8
Total export	62,689	49,502	50,705	18,130	16,699	-8

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Table 23--U.S. forage seed imports by volume

Country	1986	1987	1988	January-March 1988	January-March 1989	Change 88-89
	Metric tons					Percent
Canada	25,336	29,323	25,805	12,221	14,249	17
Argentina	372	1,006	732	128	130	2
Denmark	482	1,404	952	342	613	79
Netherlands	405	739	1,093	749	291	-61
West Germany	315	1,077	384	309	104	-66
Australia	1,264	1,797	1,218	378	107	-72
New Zealand	2,394	6,369	9,514	3,554	1,066	-70
Subtotal	30,568	41,715	39,698	17,681	16,560	-6
Total import	31,032	42,886	41,048	17,946	16,898	-6

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

seed in South America during the off-season, and much of this production entered the United States during the first quarter of the year. Argentina supplied 1,593 metric tons of corn seed in the first quarter of 1989, although it had exported no corn seed to the United States in the previous 3 years. Imports from Chile increased 28 percent in first quarter of 1989 over the first quarter of 1988; corn seed imports from Hungary soared from 35 tons in the first quarter of 1988 to 3,708 tons in the comparable period of 1989. Even though total imports are up in 1989, they rarely exceed more than 2.5 percent of domestic consumption in any single year.

Soybean Seed Exports

The drought-reduced U.S. soybean seed supplies reduced exports to Canada, France, South Korea, and Japan—some of the major U.S. soybean seed importers. These countries showed declines of 6, 44, 100, and 90 percent, respectively, in the first quarter of 1989 compared with the corresponding period of 1988 (table 21). Soybean seed exports to Italy, the largest market, decreased in 1988 from the record 44,300 metric tons in 1987. However, in the first quarter of this year, exports to Italy were above the same period in 1988 due to a shift in shipments from the last quarter of 1988.

Despite reduced U.S. supplies and higher seed prices, first-quarter exports of soybean seed to Mexico rose from none in 1988 to 38,418 metric tons in 1989. Mexico's seed supply was also affected adversely by the 1988 drought. The surge in exports to Mexico more than offset the combined declines in exports to other major trading partners. As a result, U.S. soybean seed exports rose 218 percent, by volume, in the first quarter of 1989 over the same period in 1988. Without the jump in Mexican exports, U.S. soybean seed exports would have declined 8 percent.

Forage Seed Exports

U.S. forage seed exports to the 13 major markets fell 8 percent to 14,828 metric tons in the first quarter of 1989 compared with the same quarter of 1988 (table 22). These declines can be traced to the expanded domestic seed demand and increased prices created by the CRP. Japan, Canada, Mexico, and Saudi Arabia continued to be the top markets for forage seed exports, respectively accounting for 22, 20, 8, and 6 percent of total U.S. exports by volume.

Forage Seed Imports

The combined U.S. forage seed imports from the seven major countries declined to 41,048 metric tons in 1988 from 42,886 in 1987. In the first quarter of 1989, imports registered a further decline of 6 percent from the corresponding period of 1988 (table 23). However, due to the expanding CRP, imports in 1988 were more than double those of 1985.

Canada continued to be the leading supplier of forage seeds during the first quarter of 1989, with 14,249 metric tons. The second largest source was New Zealand, with 1,066 metric tons. Grass seed imports surged in 1986 and 1987, but began falling in 1988 as domestic grass seed growers expanded production to meet increased CRP-generated demand. Also, since 1987 the number of CRP acres enrolled annually has declined.

U.S. Planting Seed Trade Balance

During the 1988 calendar year, the value of seed exports rose 13 percent from the previous year to a record $422 million (table 24). The 1988 increase primarily reflected increases in grain sorghum, forage, vegetable, flower, and corn seeds, which were up 81, 25, 21, 13 and 5 percent, respectively, from a year earlier. These gains were partly offset by declines of 28 percent in soybean seed. Tree and shrub seed exports also rose sharply, but their contribution to total seed exports was relatively modest.

Imports totaled $147 million, up 1 percent from the previous year (table 24). Although the import value of corn, tree, and shrub seeds rose 100 percent, they made only a modest contribution to the value of seed imports. The gains in other seed import categories were partly offset by a 20-percent decline in forage seed imports. The U.S. seed trade balance rose 22 percent in 1988 to a record $275 million (table 24).

Table 24--U.S. exports and imports of seeds for planting 1/

Item	1985	1986	1987	1988	Change 87-88
	Million dollars				Percent
Exports:					
Forage	59	74	75	94	25
Vegetables	120	128	138	167	21
Flower	8	9	8	9	13
Corn 2/	89	77	63	66	5
Grain sorghum	33	29	16	29	81
Soybeans	17	19	36	26	-28
Trees/Shrubs	2	2	2	3	50
Sugarbeet	2	2	1	2	100
Others	20	31	33	26	-21
Total	358	371	372	422	13
Imports:					
Forage	18	39	65	52	-20
Vegetables	34	42	49	58	18
Flower	18	18	21	21	0
Corn 3/	14	9	5	10	100
Trees/shrubs	1	1	1	2	100
Others	2	3	4	4	0
Total	87	112	146	147	1
Trade balance	271	258	226	275	22

1/ Totals may not add due to rounding. 2/ Not sweet, not food aid. 3/ Certified.

Source: U.S. Department of Commerce, Bureau of Census, Foreign Trade Division.

1988 Fall Potato Seeding Rates and Seed Costs per Acre

Although fall potato seeding rates depend largely on moisture availability during the growing season, they are also influenced by potato variety and demand by potato processors. The average seeding rate for the 11 leading fall potato-producing States in 1988 was 20 cwt per acre (table 25). The North Central States (such as North Dakota, Wisconsin, and Minnesota) have lower seeding rates, whereas those of the Pacific Northwest (Washington, Oregon, and Idaho) and the Northeast (Maine and New York) have higher seeding rates. North Dakota had the lowest seeding rate (15 cwt) per acre, since most potatoes are grown without irrigation. Areas with abundant moisture—either through rainfall, as in the Northeast, or irrigation, as in Colorado and the Pacific Northwest—tend to have higher seeding rates.

Seed potato prices also vary by region. For example, Northeast and North Central States have lower seed potato prices; the Pacific Northwest has higher prices. Variations in seed potato prices and seeding rates resulted in per acre costs ranging from $73 for North Dakota to $194 for Washington.

Farmers used purchased rather than homegrown seed potatoes on 83 percent of the 1988 fall potato acres. In Colorado, only 53 percent of the acres were planted with purchased seed, the lowest among potato-growing States. Colorado producers tend to grow a large share of their own seed potatoes, which are one or two generations away from certified seed. The other States which used a relatively smaller share of purchased seed potatoes were New York (72 percent), Maine (73 percent), and Minnesota (77 percent). Maine has a law requiring that all commercially grown potatoes use certified seed, which is mostly purchased. However, Maine has a large number of certified seed potato growers who use their own potatoes for seed production.

Table 25--Fall potato seeding rates, seed cost per acre, and percent purchased, 1988 1/

States	Acres planted	Rate per acre	Cost per acre	Acres with purchased seed
	1,000	Cwt.	Dollars	Percent
CO	60	24.0	175	53
ID	350	20.2	112	86
ME	86	22.1	146	73
MI	32	20.0	160	84
MN	70	17.4	91	77
NY	32	22.3	186	72
ND	130	15.2	73	94
OR	47	22.0	160	90
PA	22	20.1	181	91
WA	115	21.4	194	94
WI	62	18.0	117	81
Area	1,006	20.1	129	83

1/ States in survey planted 93 percent of the fall potato acreage in 1988.

Fertilizer

Use

U.S. plant nutrient use is estimated to have increased to 20.5 million tons during the 1988/89 fertilizer year (July 1-June 30), up 5 percent from the 19.5 million tons used a year earlier. Most of the increase was due to increased corn and wheat plantings. Corn acreage, which accounted for an estimated 44 percent of plant nutrient use in 1987/88, rose 8 percent; wheat acreage, which accounted for another 14 percent of nutrient use, increased by 17 percent (table 26).

While spring 1989 fertilizer prices exceeded year-earlier levels, the prices of most major crops at planting increased substantially. Although loan rates and target prices were reduced, corn prices at planting in 1989 rose over 34 percent from 1988, while last fall's winter wheat prices rose 50 percent from a year earlier. In contrast, cotton prices slipped slightly due to increased stocks.

Consequently, except for cotton, nitrogen application rates in 1989 may have increased somewhat over 1988 levels. However, rates of phosphate and potash applied may have fallen as carryover effects offset the influence of higher expected crop prices. Because phosphate and potassium are relatively immobile in most soils, 1989 application rates should reflect the unused portion of these nutrients carried over from the drought-stunted 1988 crop.

Data on fertilizer nutrient use for selected crops has appeared annually in the Situation and Outlook reports on fertilizer since 1971. Specific information provided has included the proportion of acres treated by nutrient and average nutrient application rates for corn, cotton, soybeans, and wheat. Nutrient use data is now also available for rice and potatoes, which were added to the Cropping Practices Survey in 1988. In addition, manure, lime, sulfur, and micronutrient use statistics are available for 1988 for the six crops surveyed.

Table 26--U.S. planted crop acreage

Crop	1988	1989	Change
	Million acres		Percent
Wheat	65.5	76.7	17
Feed grains	101.6	106.2	5
Corn	67.6	72.8	[illegible]
Other 1/	34.0	33.4	-2
Soybeans	58.9	61.3	4
Cotton	12.5	10.5	-16
Rice	2.9	2.8	-5

1/ Sorghum, barley, and oats.

Source: Crop Porduction, NASS, USDA, July 1989.

1988 Fertilizer Use on Rice

Fertilizer was applied to 99 percent of rice acreage in 1988; the proportion of acres treated with each nutrient ranged from 99 percent for nitrogen to 36 percent for potash (table 27). The application rate for nitrogen was 127 pounds per acre, while phosphate and potash rates stood at 47 and 50 pounds, respectively.

1988 Fertilizer Use on Fall Potatoes

Some fertilizer was applied to 95 percent of the acreage planted to fall potatoes in 1988; the proportion of acres treated ranged from 95 percent for nitrogen to 78 percent for potash (table 28). Application rates for the three nutrients varied significantly by State, averaging 185 pounds per acre for nitrogen and 151 pounds for both phosphate and potash. North Dakota acreage received the least amount of all fertilizer nutrients, while Washington and Wisconsin received the most.

1988 Use of Manure, Lime, Sulfur, and Micronutrients

Manure was applied to 18 percent of all corn acres surveyed in 1988; use ranged from 47 percent in Wisconsin to 2 percent in Missouri (table 29). Manure use on other crop acreage surveyed was less common, ranging from 6 percent for soybeans to 1 percent for rice. Micronutrient use also varied considerably by crop; almost half of the potato acres planted received micronutrients in 1988, while only 2 percent of the wheat acres were similarly treated.

Using lime to balance a soil's pH (a measure of its acidity or alkalinity) increases the yield potential of crops by improving the availability of soil nutrients. The frequency of lime applications can range from every year on highly acidic soils to every 5-10 years on the more alkaline soils in the Midwest. Lime was applied to 6 percent of the corn and fall potato acres surveyed in 1988, but no lime was used on rice or durum wheat. Lime application rates ranged from 2.3 tons per acre for winter wheat to 1.1 tons for fall potatoes.

Like other essential nutrients, sulfur plays a unique role in plant growth. Plants deficient in sulfur are often small and spindly, and in legumes, such a deficiency can reduce root nodulation. Sulfur use was more common than lime on all crops surveyed except soybeans. Sulfur use was most prevalent on fall potatoes; calcium sulfate is frequently applied to potatoes to extend their storage life. Forty percent of potato acres surveyed received an average of 49 pounds of sulfur per acre in 1988.

Supplies

The U.S. Department of Commerce discontinued the reporting of anhydrous ammonia imports in January 1989 because of a filed disclosure complaint by a fertilizer importer. Consequently, 1987/88 and 1988/89 nitrogen supplies include only that share of anhydrous ammonia imported during July-December to preserve the validity of year-to-year comparisons. Imports of anhydrous ammonia account for a significant portion of total U.S. nitrogen imports: in 1987/88, anhydrous ammonia imports accounted for 66 percent of total nitrogen imports, while during January-May

Table 27--Fertilizer use on rice, 1988

State	Acres planted	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P2O5	Acres receiving: K2O	Application rates: N	Application rates: P2O5	Application rates: K2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000	No.	Percent				Pounds per acre			Percent		
Arkansas	1,180	243	99	99	23	30	131	42	57	5	58	37
California	425	145	98	98	85	14	131	52	44	78	1	22
Louisiana	525	156	99	98	67	66	114	47	44	15	64	21
Area	2,130	544	99	99	46	36	127	47	50	22	48	30

Table 28--Fertilizer use on fall potatoes, 1988

State	Acres planted	Fields in survey	Acres receiving: Any fertilizer	Acres receiving: N	Acres receiving: P2O5	Acres receiving: K2O	Application rates: N	Application rates: P2O5	Application rates: K2O	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000	No.	Percent				Pounds per acre			Percent		
Colorado	60	80	100	100	99	49	157	144	58	17	6	77
Idaho	350	306	95	95	92	64	223	164	91	27	6	68
Maine	86	151	100	100	100	100	162	174	175	96	0	4
Michigan	32	105	99	98	97	99	157	145	218	38	3	59
Minnesota	70	127	93	91	91	88	106	79	144	68	3	29
New York	32	80	88	88	85	80	158	229	199	77	0	23
North Dakota	130	136	95	95	93	92	91	85	72	82	0	18
Oregon	47	117	97	97	97	82	240	176	127	34	0	66
Pennsylvania	22	92	100	100	100	100	173	143	159	62	0	38
Washington	115	178	94	94	89	74	249	186	225	43	0	57
Wisconsin	62	110	99	99	98	99	199	155	386	15	0	85
Area	1,006	1,482	95	95	93	78	185	151	151	46	3	51

Table 29--Manure, lime, sulfur, and micronutrient use on selected crops, 1988

Crop	Acres 1/	Acres receiving: Manure	Lime	Sulfur	Micro-nutrients	Application per acre: Lime	Sulfur
	1,000	Percent				Tons	Pounds
Corn	53,200	18	6	10	11	1.9	11
Cotton	9,700	4	2	15	18	1.3	10
Potatoes	1,006	3	6	40	49	1.1	49
Rice	2,130	1	nr	7	17	nr	19
Soybeans	48,750	6	5	1	3	1.6	9
Wheat:							
All	45,110	2	1	6	2	2.2	12
Durum	2,500	4	nr	nr	nr	nr	nr
Spring	9,780	3	*	3	1	1.6	15
Winter	32,830	2	1	8	2	2.3	12

nr = None reported. * = Less than 0.5 percent.

1/ Includes the major producing States for each crop. Information is based on harvested acres for winter wheat and planted acres for all other crops.

Table 30--U.S. fertilizer supplies 1/

Item	1987/88	1988/89	Change
	Million short tons		Percent
July 1 inventory:			
Nitrogen (N)	1.36	1.35	0
Phosphate (P_2O_5) 2/	.51	.55	10
Potash (K_2O)	.22	.16	-27
Production:			
Nitrogen	12.34	12.90	5
Phosphate 2/	10.44	10.82	4
Potash	1.40	1.50	7
Imports:			
Nitrogen	3/ 2.54	3/ 3.13	23
Phosphate 2/	.15	.07	-57
Potash	4.50	3.89	-14
Exports:			
Nitrogen	2.74	2.61	-5
Phosphate 2/	4/ 3.76	4/ 4.21	12
Potash	.43	.36	-17
Domestic supply: 5/			
Nitrogen	3/ 13.50	3/ 14.76	9
Phosphate 2/	4/ 7.34	4/ 7.23	-1
Potash	5.69	5.19	-9

1/ Data for July through May for the fertilizer year starting July 1. 2/ Does not include phosphate rock. 3/ Does not include imports of anhydrous ammonia during January-May 1987/88 or 1988/89; anhydrous ammonia import reports were discontinued by the U.S. Department of Commerce in January 1989. Imports of anhydrous ammonia during January-May accounted for 30 percent of total nitrogen imports in 1987/88; thus, nitrogen imports and domestic supply are significantly understated. Also, aqua ammonia imports include only January-April 1989. 4/ Does not include exports of superphosphoric acid in 1987/88 or July-December 1988/89 because of a data reporting change by the U.S. Department of Commerce. Thus, phosphate exports are understated and domestic supply is overstated. 5/ Includes requirements for industrial uses.

1988 they made up 30 percent. Thus, nitrogen imports and domestic supply are significantly understated in this report.

Domestic supplies of phosphate and potash in 1988/89 declined from a year earlier, but nitrogen supplies increased.

Nitrogen supplies went up 9 percent during July-May as net imports increased and production rose 5 percent (table 30). Phosphate supplies fell 1 percent because a 12-percent rise in exports more than offset increased production. Potash supplies fell by 9 percent because imports dropped 14 percent.

Trade

The rapid growth in domestic and international purchases of fertilizer materials in the first 6 months of fertilizer year 1988/89 has not continued. Some slowdown in fertilizer purchases by dealers and farmers was expected following the heavy buying towards the close of 1988, which was prompted by anticipation of strong domestic and international 1989 spring demand. In addition, the U.S. dollar has grown stronger against foreign currencies, gaining about 10 percent since the first of the year. The increased value of the dollar on world markets has made U.S. fertilizer products more expensive in local currencies than similar foreign products.

U.S. phosphate exports during July-May increased 12 percent, but nitrogen exports fell 5 percent from the strong export market for both nutrients in 1987/88. Potash exports of only 362,000 tons were off by 17 percent from a year earlier. The decline in potash exports follows a 16-percent drop from 1986/87 to 1987/88.

The volume of fertilizer materials exported from the United States varied compared with year earlier-levels. For July-May, diammonium phosphate exports climbed 17 percent from 5.9 to 6.9 million tons, and monoammonium phosphate exports increased 37 percent from 621,000 to 848,000 tons. Exports of most other fertilizer materials decreased. Phosphate rock exports also increased slightly from 9.1 to 9.2 million tons.

Nitrogen solutions exports, although still much higher than earlier years, declined 20 percent from 798,000 to 642,000 tons. Anhydrous ammonia exports fell 33 percent from 856,000 to 565,000 tons. Urea exports dropped 7 percent from 971,000 to 902,000 tons, and concentrated superphosphate exports plunged 39 percent from over 1 million to 633,000 tons. Exports of ammonium nitrate, ammonium sulfate, potassium chloride, and potassium sulfate decreased 46, 8, 7, and 41 percent, respectively.

Western Europe, Asia, Canada, and Latin America (principally France, Belgium, Italy, India, Japan, China, Pakistan, Korea, Mexico, and Brazil) continued to be major recipients of U.S. fertilizer. During July-May, over 44 percent of urea exports and 26 percent of diammonium phosphate exports—representing 402,000 and 1.8 million tons of product, respectively—went to China. Fertilizer consumption in China has grown rapidly during the past few years, making it the world's third largest consumer of manufactured fertilizer nutrients after the Soviet Union and the United States. The Chinese have replaced the old commune system with the household contract system in which each family group assumes responsibility for a plot of land. Farm output and fertilizer use have increased dramatically.

U.S. exports of urea to the European Community (EC) have become less competitive since the change in the antidumping ruling of February 1989. The EC softened its antidumping rulings for several countries that provided assurances about quantities being exported to EC nations. However, none of the U.S. duty decisions made during the case were changed, since U.S. companies could state only their own and not any other U.S. party's export intentions. As a result, urea imported into the EC from Hungary, Romania, Malaysia, and Austria had duties of 2-50 percent removed in favor of the voluntary understandings (export quantity assurances). The EC has lowered Saudi Arabia's antidumping duty from 40 to 12.8 percent, and Venezuela's from 35 to 21.5 percent. All of the adjusted measures are now definitive until the rulings expire at the end of 1992 (for 1987 rulings) and at the beginning of 1994 (for 1988/89 rulings).

France remains an important buyer of U.S. nitrogen solutions, receiving 353,000 tons (55 percent) of these exports during July-May. Belgium-Luxembourg accounted for 220,000 tons (34 percent) of U.S. exports. Brazil received 420,000 tons or 55 percent of ammonium sulfate exports, and 228,000 tons or 53 percent of potassium muriate exports. Bangladesh received 225,000 tons or 36 percent of concentrated superphosphate exports. Phosphate rock exports have remained strong, with South Korea, Canada, Japan, the Netherlands, France, and Poland being the major recipients.

Fertilizer material imports for most products exceeded year-earlier levels. Exceptions to this trend are potassium chloride imports, which were down 14 percent from 7.3 to 6.3 million tons, and diammonium phosphate imports, which decreased 59 percent from 29,000 to 12,000 tons. However, imports of potassium chloride from Canada remained strong at around 89 percent of the total, and imports from the Soviet Union increased 8 percent from 241,000 to 260,000 tons. Imports from Israel plummeted 60 percent from 437,000 to 260,000 tons.

Compared with a year earlier, imports of fertilizer material increased for several products. Urea imports climbed 3 percent from 2.0 to 2.2 million tons, with Canada supplying about 49 percent of the total. Nitrogen solutions imports rose 13 percent from 569,000 to 576,000 tons. Ammonium nitrate imports soared 66 percent from 219,000 to 363,000 tons, and ammonium sulfate imports jumped 22 percent from 280,000 to 341,000 tons. Imports of potassium sulfate, potassium nitrate, and sodium nitrate also increased.

Production

Domestic fertilizer production expanded for each of the primary plant nutrients during 1988/89 in response to higher prices and greater use. Nitrogen production rose 5 percent during July-May because many anhydrous ammonia producers operated near maximum capacity. Phosphate production advanced 4 percent in response to continued strength in the export market; potash production went up 7 percent.

Prices

Tighter fertilizer supplies due primarily to greater U.S. demand in 1988/89 boosted prices. Aggregate farm fertilizer prices in spring 1989 increased 7 percent from a year earlier, and 5 percent from October 1988 (table 31 and fig. 4). The rise marked the third consecutive annual increase in fertilizer prices; the prices paid index for fertilizer has risen steadily since the fall of 1986. However, average prices paid remained more than 4 percent below the peaks of the early 1980's.

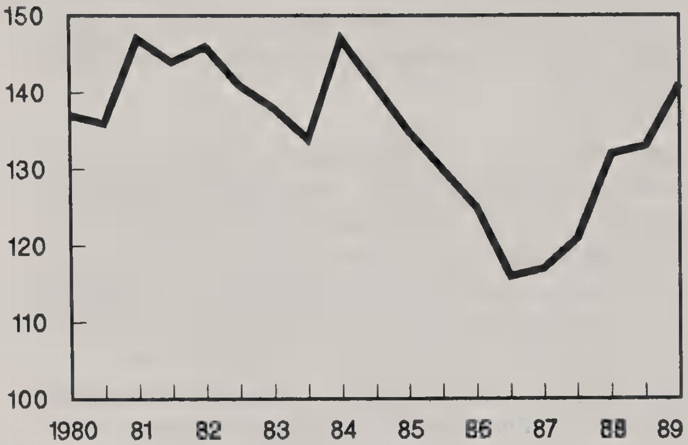
Nitrogen prices showed the greatest gain since last fall, with anhydrous ammonia prices climbing more than 17 percent by April due to increased domestic use. Prices of other nitrogen materials also increased from 4 to 13 percent. Triple superphosphate and diammonium phosphate prices went up

Table 31--Average U.S. farm prices for selected fertilizer materials 1/

Year	Anhydrous ammonia (82%)	Triple super-phosphate (44-46%)	Diammonium phosphate (18-46-0%)	Potash (60%)	Mixed (6-24-24%)	Prices paid index 1977=100
	Dollars per short ton					
1986	225	190	224	111	179	125
1987	187	194	220	115	176	117
1988	208	222	251	157	208	132
1989	224	229	256	163	217	141

1/ Based on surveys of farm supply dealers conducted by the the NASS, USDA. Prices are for April.

Figure 4
U.S. fertilizer price index



May and October data for 1980-85; April and October data for 1986-89.

4 percent. Potash prices also increased slightly; the price of potassium chloride reached $163 per ton in April.

The U.S. Department of Transportation (DOT) has decided to retain the current classification of anhydrous ammonia as a nonflammable gas, rather than reclassify the material as a poisonous gas, as proposed in 1987. DOT has also proposed that the words "INHALATION HAZARD" be required on packages and shipping papers, in addition to other hazard communication requirements.

On July 26, 1989 President George Bush signed the natural gas deregulation bill, lifting the last of federal controls on natural gas. Natural gas at the wellhead will be deregulated by May 15, 1991 and all natural gas by January 1, 1993.

Pesticides

Demand

Total 1989 farm pesticide use on major field crops is projected at 463 million pounds, active ingredients (a.i.), up from 439 million in 1988 (table 32). June 1 planted acreage for the 10 major field crops increased from 243 million in 1988 to 260 million. The area planted to corn, grain sorghum, soybeans, tobacco, and wheat went up, while acreage of cotton, barley, oats, and rice declined. Peanut acreage held steady at 1.7 million acres.

Most of the increase in pesticide use can be attributed to the rise in corn acreage, which is up 5.2 million from a year earlier. Corn accounts for 56 percent of herbicide and 44 percent of insecticide use. Peanuts account for 80 percent of the fungicides used on major field crops.

Table 32--Projected pesticide use on major U.S. field crops, 1989

Crops	June 1 planted acres	Herbicides	Insecticides	Fungicides
	Million	Million pounds (a.i)		
Row:				
Corn	72.8	219	27.1	0.06
Cotton	10.5	16	15.6	.16
Grain sorghum	11.9	11	1.9	0
Peanuts	1.7	6	1.3	6.19
Soybeans	61.3	108	9.5	.06
Tobacco	.7	1	2.7	.35
Total	158.9	361	58.1	6.82
Small grains:				
Barley and oats	21.4	5	.2	0
Rice	2.8	12	.5	.07
Wheat	76.7	16	2.2	.88
Total	100.9	33	2.9	.95
Total	259.9	394	61.0	7.77
1988 total	243.4	372	59.7	7.56

Table 33--U.S. average farm retail pesticide prices

Pesticide 1/	1987	1988	1989	Change 1988-89
	Dollars per pound 2/			Percent
Herbicides:				
Alachlor	4.84	5.10	5.40	5.9
Atrazine	2.20	2.28	2.70	18.4
Butylate	3.04	3.10	3.10	0.0
Cyanazine	4.63	4.78	5.03	5.2
Metolachlor	6.03	6.21	6.61	6.4
Trifluralin	6.30	6.45	6.60	2.3
2,4-D	2.44	2.53	2.60	2.8
Composite 3/	4.05	4.20	4.43	5.5
Insecticides:				
Carbaryl	3.90	4.06	4.07	0.2
Carbofuran	9.57	9.36	9.51	1.6
Chlorpyrifos	8.25	8.50	9.05	6.5
Fonofos	8.70	8.83	8.96	1.5
Methyl parathion 4/	2.82	2.94	3.85	31.0
Phorate	6.59	6.68	6.85	2.5
Pyrethroids 5/	48.80	50.00	53.20	6.4
Terbufos	9.79	9.88	10.13	2.5
Composite 3/	10.25	10.57	10.88	2.9

1/ Derived from the April survey of farm supply dealers conducted by the NASS, USDA. 2/ Active ingredients. 3/ Includes above materials and other major materials but not products registered in the last 2 to 3 years. 4/ Supplied by Fred Cooke, Mississippi Agricultural Experiment Station. 5/ Average of fenvalerate and permethrin prices based on 2.6 pounds active ingredient per gallon.

Prices

Herbicide and insecticide prices have shown a general rise over the past 3 years (table 33). Pesticide manufacturing costs have gone up, and the increase in the planted acreage of crops that require intensive pesticide use has heightened demand. Dealer costs (especially liability insurance) also have risen, putting additional upward pressure on retail prices.

Average farm-level herbicide prices rose 5.5 percent between 1988 and 1989, following a 3.7-percent increase a

year earlier. Atrazine, a major corn and grain sorghum herbicide, showed the greatest increase—18.4 percent. At $2.70 per pound a.i., the atrazine price is the highest farmers have paid since 1981 (when it stood at $2.72) and matches that of 1977. Between 1968 and 1976, atrazine ranged between $2.80 and $3.70 per pound.

Farm-level insecticide prices are projected to be up 2.9 percent, compared with an increase of 3.1 percent last year. This year, prices for methyl parathion (used extensively to control boll weevils in cotton production) are up a whopping 31 percent. Spring trappings in 1989 indicated the possibility of heavy boll weevil pressure. Growers therefore stocked up on methyl parathion, tightening supplies and increasing the price.

Weed Control Methods

Farmers in the major producing States treat about 95 percent of their corn, soybean, and cotton acreage with herbicides to control weeds. In addition, mechanical cultivation is used to eliminate weeds in the row middles during the growing season.

Cultivation

In 1988, farmers in the 10 major corn-producing States cultivated 80 percent of their acreage during the growing season to control weeds (table 34). In Michigan and Ohio, slightly over 50 percent of the corn acreage received no mechanical weed control. These States have more than 10 percent of their corn acreage in no-till systems.

Most farmers cultivated once, but in South Dakota and Nebraska (which has irrigated corn) two cultivations were performed on 62 and 45 percent of the acreage, respectively. In South Dakota only about 80 percent of the corn acreage is treated with herbicides, necessitating increased cultivations to control weeds, while on Nebraska's irrigated corn acreage, a second cultivation is often necessary before gravity irrigation can begin.

There is a distinct difference in the average number of weed control cultivations between the Northern and Southern soybean production regions, 1.5 vs. 2.2 (table 35). The South's longer growing season and higher precipitation render weed pressure greater in that region.

However, in the South 42 percent of the soybean acreage received no cultivations, compared with 29 percent in the Northern region. Kentucky and North Carolina had the highest proportion of soybean acreage not cultivated—72 and 58 percent, respectively. These States also have the highest proportion of no-till soybean acreage at 30 and 24 percent, respectively.

Cotton growers cultivated an average of 3.3 times during the growing season (table 36). The Delta States and the irrigated acreage in the West showed the highest number of cultivations. In Texas, 11 percent of the cotton acreage was cultivated once, and 30 percent twice. Much of the cotton in Texas is grown in arid areas were weed pressure is lower. Early in the season, the cotton plant develops slowly and cannot compete well against weeds. Therefore, it must be protected from weeds to achieve optimum production.

When Herbicides Are Applied

Growers may apply herbicides before, at, or after planting, or several times during the year. The timing of herbicide applications depends on: the farmer's knowledge of the weed problems and aversion to risk; herbicide costs per acre; and available application technology (for example, spray equipment mounted on the planter, self-propelled spray equipment, custom operators). To insure that the crop gets off to a good start, weed competition must be minimized for

Table 34--Distribution of corn acres by number of cultivations, 1988 1/

State	Number of cultivations: 0	1	2	3	Average cultivations
	Percent				Number
Illinois	22	70	8	nr	1.11
Indiana	39	54	7	1	1.11
Iowa	11	71	17	1	1.22
Michigan	53	40	7	nr	1.15
Minnesota	4	62	32	2	1.37
Missouri	34	57	4	1	1.19
Nebraska 2/	10	62	27	4	1.33
Nebraska 3/	7	44	45	4	1.57
Ohio	51	43	6	1	1.15
South Dakota	3	33	62	3	1.69
Wisconsin	23	58	18	1	1.25
Area	20	59	20	1	1.28

nr = None reported.

1/ These States planted 53.2 million acres of corn (79 percent of U.S. total). 2/ Dryland. 3/ Irrigated.

Table 35--Distribution of soybean acres by number of cultivations, 1988 1/

Region, State	Number of cultivations: 0	1	2	3	4	>4	Average cultivations
	Percent						Number
Northern:							
Illinois	28	46	25	1	nr	nr	1.38
Indiana	29	42	28	nr	nr	nr	1.40
Iowa	13	49	35	3	nr	nr	1.47
Minnesota	30	28	35	7	nr	nr	1.71
Missouri	35	42	17	3	1	nr	1.47
Nebraska	22	58	21	nr	nr	nr	1.26
Ohio	60	25	15	1	nr	nr	1.41
Area	29	42	27	2	*	nr	1.45
Southern:							
Arkansas	31	15	27	16	7	3	2.38
Georgia	13	16	46	22	2	nr	2.13
Kentucky	72	17	11	nr	nr	nr	1.38
Louisiana	47	14	16	18	4	2	2.33
Mississippi	38	13	23	20	5	1	2.33
N. Carolina	58	8	17	15	2	nr	2.25
Tennessee	49	20	23	8	nr	nr	1.76
Area	42	14	23	15	4	1	2.22

nr = None reported. * = Less than 1 percent.

1/ These States planted 48.8 million acres of soybeans (83 percent of U.S. total).

Table 36--Distribution of cotton acres by number of cultivations, 1988 1/

State	Number of cultivations: 0	1	2	3	4	5	6	>6	Average cultivations
	Percent								Number
Arizona	2	nr	19	19	18	21	12	8	4.30
Arkansas	nr	nr	9	18	43	20	8	3	4.10
California	9	3	11	20	25	21	8	3	3.98
Louisiana	5	2	15	28	26	15	3	6	3.73
Mississippi	5	nr	11	34	31	13	5	1	3.71
Texas	2	11	30	31	20	6	nr	nr	2.81
Area	4	7	22	28	24	11	3	2	3.29

nr = None reported.

1/ These States planted 9.7 million acres of cotton (81 percent of U.S. total).

4 to 8 weeks after planting, for during this period the soil surface is bare, and germinating weeds compete with the plant for water, nutrients, and space. Once the plant develops enough foliage to shade the ground, competition from germinating weeds is reduced.

If a farmer knows from past experience that a severe weed problem exists, he or she will try to minimize yield losses during that critical 4-8 weeks. Rainfall during this period affects the farmer's ability to get into the field to apply herbicides. Risk aversion, application technology, and herbicide costs per acre now influence the farmer's decision.

After-planting applications may be made with either preemergence (before weeds emerge) or postemergence (after weeds emerge) herbicide materials. Preemergence materials need to be applied within a few days after planting, or the weeds will have emerged, rendering the material ineffective. Postemergence materials have a longer timeframe for application, but as weeds get larger they become more difficult to control. As a rule, preemergence herbicides tend to be more costly. Postemergence materials, on the other hand, are generally applied at lower a.i. rates per acre.

The large proportion of acreage treated with herbicides before and at planting indicates that farmers follow a risk-averse strategy with respect to controlling weeds. Farmers typically apply herbicides before weeds germinate rather than waiting to see what weed problems develop before applying a herbicide.

Applying herbicides only before planting constituted the most common treatment in cotton and soybean production (table 37). In corn production, after-planting was the most common herbicide treatment (31 percent), followed by before-planting applications (28 percent). Comparing 1988 and 1984 data indicates that farmers' timing of herbicide applications has changed little over the past 5 years, although before-planting applications may have increased somewhat for soybeans and cotton.

Sequential before- and after-planting treatments were common in corn and soybean production, while before-, at-, and after- treatments were used on 13 percent of the herbicide-treated cotton acreage. Sequential herbicide applications were used on 40 percent of the treated cotton acreage, reflecting the intensity of weed pressure during the season.

How Herbicides Are Applied

A broadcast treatment with ground equipment spraying the entire surface area of the field comprises the most common

Table 37--Distribution of herbicide-treated acres by application timing, 1988 1/

Time applied	Corn	Soybeans	Cotton
		1,000	
Acres treated with herbicides	51,301	46,920	9,234
		Percent	
Application timing: 2/			
1. Before planting	28 (26)	40 (31)	45 (30)
2. At planting	18 (20)	12 (14)	10 (10)
3. After planting	31 (32)	17 (12)	5 (*)
1 + 2	1	4	12
1 + 3	15	22	11
2 + 3	7	4	4
1 + 2 + 3	*	1	13
Total	100	100	100

* = Less than 1 percent.

1/ See tables 34, 35, and 36 for a listing of States.
2/ Data in parenthesis are from 1984. Sequential application data for 1984 are not comparable due to different tabulation methods.

Source: Inputs Outlook and Situation, IOS-7, February 1985.

method of applying herbicides in corn, soybean, and cotton production (table 38). However, the application method varies with the timing of the treatment.

Before-planting applications are generally made with the broadcast method. The herbicide may be incorporated into the soil with a tillage implement or moved into the soil by rain.

For corn and soybeans, at-planting applications are divided between broadcast and banded (when only the surface area over the crop row is treated) applications. In cotton, 80 percent of the at-planting acre-treatments are banded over the crop row. The spray band is generally 10 to 13 inches wide, and weeds in the row middles are controlled by mechanical cultivation during the season. By banding the herbicide in the crop row, the farmer reduces by two-thirds the pounds of active ingredient applied per acre. In 1984, banded applications accounted for 42 percent of the corn, 46 percent of the soybean, and 65 percent of the cotton acreage receiving at-planting herbicide acre-treatments: this suggests that banding increased for corn and cotton, and stayed the same for soybeans.

Table 38--Herbicide acre-treatments: when and how applied in corn, soybean, and cotton production, 1988 1/

	Relationship to planting			
	Before	At	After	Total
Corn:				
1,000 acre-treatments with herbicides	23,227	13,481	30,761	67,469
Percent of acre-treatments	34	20	46	100
Application method--				
Broadcast, ground	97	43	84	81
Broadcast, air	*	*	1	*
Irrigation water	nr	nr	*	*
Banded in/over row	4	56	3	14
Directed spray	na	na	11	5
Soybeans:				
1,000 acre-treatments with herbicides	32,761	10,326	24,525	67,612
Percent of acre-treatments	49	15	36	100
Application method--				
Broadcast, ground	95	54	73	80
Broadcast, air	1	2	5	3
Banded in/over row	4	44	13	13
Directed spray	na	na	10	4
Cotton:				
1,000 acre-treatments with herbicides	7,719	3,728	5,340	16,787
Percent of acre-treatments	46	22	32	100
Application method--				
Broadcast, ground	88	19	20	51
Broadcast, air	3	1	1	2
Banded in/over row	9	80	38	34
Directed spray	na	na	41	13

* = Less than 1 percent. nr = None reported.
na = Not applicable.

1/ See tables 34, 35, and 36 for a listing of States.

About 80 percent of the after-planting corn and soybean herbicide acre-treatments consisted of broadcast applications with ground equipment. In cotton, however, 38 percent of the acre-treatments were banded, and 41 percent were applied as a directed spray. With directed sprays, drop nozzles are used to place the herbicide material at the base of the plant under the leaf canopy. Several postemergence herbicides used in cotton production carry a label instruction to "keep off the foliage," because the spray material can damage the cotton plant, delaying maturity and reducing yields.

Pesticide Use on Rice

In 1988, herbicides were used on 98 percent, insecticides on 18 percent, and fungicides on 14 percent of the rice acreage in the surveyed States—Arkansas, California, and Louisiana (table 39). No foliar fungicides were reported to have been used in California, because none are registered for the dis-

Table 39--Rice acres treated with pesticides, 1988 1/

Category, State	Planted acres	Treated acres	Percent treated
	1,000	1,000	
Herbicides:			
Arkansas	1,180	1,169	99
California	425	420	99
Louisiana	525	489	93
Area	2,130	2,078	98
Insecticides:			
Arkansas	1,180	21	2
California	425	250	59
Louisiana	525	112	21
Area	2,130	383	18
Fungicides:			
Arkansas	1,180	176	15
Louisiana	525	64	12
Area	1,705	240	14

1/ States planted 74 percent of the rice acreage.

Table 40--Rice acres treated with pesticides by number of treatments, 1988 1/

	Number of treatments					Average acre-treatments
Category, State	1	2	3	4	5	
	Percent					Number
Herbicides:						
Arkansas	29	48	21	2	nr	1.98
California	19	58	22	1	1	2.07
Louisiana	56	39	4	1	nr	1.50
Area	33	48	17	1	*	1.88
Insecticides:						
Arkansas	100	nr				1.00
California	82	18				1.18
Louisiana	93	7				1.07
Area	86	14				1.14
Fungicides:						
Arkansas	91	9				1.09
Louisiana	90	10				1.10
Area	90	10				1.10

nr = None reported. * = Less than 1 percent.

1/ See table 39 for acres treated.

ease problems of stem rot and sheath spot common in that State.

About half of the rice acreage received two herbicide treatments. Insecticides and fungicides were generally used only once (table 40).

Propanil was the most commonly used herbicide in rice production, either alone or in tank mixes with other materials to broaden the spectrum of control (table 41). Molinate ranked second in importance. Both are used primarily to control barnyardgrass, although they also control a variety of other grass and broadleaf weeds. Bentazon and MCPA are used extensively in California rice production to control broadleaf weeds and sedges.

Carbofuran was used in all three States to control the rice water weevil. Methyl parathion is used to control rice stink bugs and grasshoppers; in California, it is also used to control tadpole shrimp. Tadpole shrimp control plays a vital role in California rice production because a large proportion of the acreage is water-seeded. As the rice seed germinates, the shrimp cut off the sprout. Later, as they burrow into the soil to lay eggs, they damage the roots of the rice seedling. Although not included in table 41, copper sulfate was reportedly used on 35 percent of the rice area in California, primarily for shrimp control.

Table 41--Selected pesticides used in rice production, 1988

Item	AR	CA	LA	Area
1,000 acres treated with herbicides	1,169	420	489	2,078
		Percent		
Acre-treatments by active ingredients:				
Single materials--				
Bentazon	1	39	2	9
Thiobencarb	5	26	4	9
Bromoxynil	nr	5	8	1
MCPA	nr	44	1	9
Molinate	31	68	25	37
Propanil	105	6	53	72
2,4-D	17	1	31	17
Fenoxaprop-ethyl	6	nr	1	4
Other	4	2	2	3
Tank mixes--				
Bentazon + MCPA	nr	12	nr	2
Bentazon + propanil	nr	1	9	3
Thiobencarb + propanil	15	nr	4	9
Molinate + propanil	4	nr	2	3
Other tank mixes	9	4	9	8
Average acre-treatments	1.98	2.07	1.50	1.88
1,000 acres treated with insecticides	21	250	112	383
		Percent		
Acre-treatments by active ingredient:				
Single materials--				
Carbofuran	75	61	93	71
Methyl parathion	nr	49	10	35
Other	25	9	4	8
Average acre-treatments	1.00	1.18	1.07	1.14
1,000 acres treated with fungicides	176	nr	64	240
		Percent		
Acre-treatments by active ingredients:				
Single materials--				
Benomyl	77	nr	62	73
Propiconazol	29	nr	49	34
Other	3	nr	nr	3
Average acre-treatments	1.09		1.10	1.10

Sheath blight, caused by a soil-borne organism, poses the gravest disease problem in rice production. It kills the foliage, thereby reducing yields. Benomyl and propiconazol are only partially effective—they can only slow the development of sheath blight, not control it.

Pesticide Use on Fall Potatoes

Fall potatoes are grown across the northern United States, from Maine to Washington. Herbicides were applied to 77 percent of the fall potato acreage in the 11 surveyed States (table 42). However, in Minnesota and North Dakota, where rainfall is low, only one-third of the acreage was treated with herbicides. Insecticide use was fairly uniform across all States. The proportion of acreage treated with fungicides was highest in the humid eastern States and lowest in the more arid western States.

Herbicides were applied once on 80 percent of the fall potato acreage, and twice on 18 percent (table 43). Insecticide acre-treatments averaged 2.2, ranging from 1.2 in Colorado and Idaho to 3.4 in New York (table 44). Fungicide acre-treatments were highest in Maine at 9.2, followed by Wisconsin at 5.1 (table 45). In the Pacific Northwest and Colorado, average acre-treatments ranged from 1.1 to 1.6.

Herbicides

Metribuzin was the most commonly used herbicide in fall potato production (table 46). It was either used alone or tank-mixed with other herbicides to broaden the weed control spectrum. Metribuzin requires moisture shortly after

Table 42--Pesticide use on fall potatoes, 1988 1/

State	Acres planted	Acres treated with Herbicides	Acres treated with Insecticides	Acres treated with Fungicides
	1,000		Percent	
Colorado	60	55	60	89
Idaho	350	80	79	24
Maine	84	100	100	100
Michigan	32	96	96	89
Minnesota	70	32	100	84
New York 2/	24	100	98	100
North Dakota	130	37	100	88
Oregon	47	85	95	62
Pennsylvania	22	93	98	92
Washington	115	92	91	55
Wisconsin	62	88	99	99
Area	998	77	89	62

1/ These States planted 92 percent of the fall potato acreage. 2/ Excludes Long Island.

Table 43--Fall potato acres treated with herbicides by number of treatments, 1988

State	Number of treatments 1	2	3	4	Average acre-treatments
	Percent				Number
Colorado	98	2	nr	1	1.02
Idaho	74	24	2	nr	1.28
Maine	96	3	nr	1	1.07
Michigan	69	31	nr	nr	1.31
Minnesota	89	3	6	3	1.22
New York 1/	83	17	nr	nr	1.17
North Dakota	85	15	nr	nr	1.15
Oregon	56	23	13	8	1.73
Pennsylvania	80	20	nr	nr	1.20
Washington	83	17	nr	nr	1.17
Wisconsin	80	18	2	1	1.23
Area	80	18	2	*	1.23

nr = None reported. * = Less than 1 percent.

1/ Excludes Long Island.

Table 44--Fall potato acres treated with insecticides by number of treatments, 1988

State	Number of treatments 1	2	3	4	5	6	>6	Average acre-treatments
	Percent							Number
Colorado	79	19	2	nr	nr	nr	nr	1.23
Idaho	81	16	2	1	nr	nr	nr	1.24
Maine	19	34	28	5	6	8	1	2.75
Michigan	35	29	19	5	6	6	nr	2.34
Minnesota	20	22	27	17	8	5	2	2.95
New York 1/	4	26	43	9	nr	4	13	3.44
North Dakota	28	13	25	24	9	nr	nr	2.73
Oregon	36	27	17	17	4	nr	nr	2.25
Pennsylvania	10	23	34	12	20	nr	2	3.16
Washington	21	20	28	6	5	19	nr	3.11
Wisconsin	42	36	16	4	nr	1	nr	1.86
Area	45	21	17	8	4	4	1	2.20

nr = None reported.

1/ Excludes Long Island.

Table 45--Fall potato acres treated with fungicides by number of treatments, 1988

State	Number of treatments 1	2	3	4	5	6	7	8	9	10	11	12	>12	Average acre-treatments
	Percent													Number
Colorado	59	22	15	4	nr	nr	nr	nr	nr	nr	nr	nr	nr	1.63
Idaho	88	10	2	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	1.14
Maine	4	2	2	nr	nr	3	7	16	17	21	15	8	7	9.19
Michigan	67	1	9	9	4	4	nr	4	nr	nr	3	nr	nr	2.32
Minnesota	34	24	16	13	1	3	2	1	nr	3	1	nr	1	2.90
New York 1/	38	34	9	9	2	2	6	nr	nr	nr	nr	nr	nr	2.34
North Dakota	55	12	11	15	7	nr	nr	nr	nr	nr	nr	nr	nr	2.06
Oregon	56	34	5	5	nr	nr	nr	nr	nr	nr	nr	nr	nr	1.60
Pennsylvania	18	16	13	19	19	6	3	1	4	nr	1	nr	nr	3.77
Washington	58	34	4	3	nr	nr	nr	nr	nr	nr	nr	nr	nr	1.53
Wisconsin	16	9	14	15	3	7	8	8	3	13	1	2	nr	5.10
Area	46	16	9	8	2	2	2	3	3	4	2	1	1	3.26

nr = None reported.

1/ Excludes Long Island.

Table 46--Selected herbicides used in fall potato production, 1988

Item	CO	ID	ME	MI	MN	NY 1/	ND	OR	PA	WA	WI	Area
1,000 acres treated with herbicides	33	307	86	31	23	24	48	40	21	105	55	773
Percent acre-treatments by active ingredients: 2/												
Single materials--												
EPTC	44	23	1	nr	8	2	26	42	3	22	nr	18
Linuron	nr	1	32	55	3	23	nr	nr	2	nr	14	8
Metolachlor	nr	nr	nr	5	6	4	9	9	1	nr	5	2
Metribuzin	29	72	68	44	28	19	30	64	39	40	48	55
Pendimethalin	nr	4	1	nr	25	6	9	21	nr	4	nr	5
Other single materials	nr	2	2	nr	33	6	41	4	20	8	18	8
Tank mixes--												
EPTC + metribuzin	13	15	2	2	3	nr	nr	10	1	24	3	11
EPTC + trifluralin	nr	6	nr	nr	nr	nr	nr	5	nr	1	nr	3
Linuron + metolachlor	nr	nr	nr	9	3	13	nr	nr	10	nr	2	1
Metolachlor + metribuzin	15	1	1	4	nr	19	nr	nr	38	1	25	5
Metribuzin + pendimethalin	nr	3	nr	nr	11	nr	nr	7	1	15	5	4
Other tank mixes	2	1	1	12	3	23	nr	12	4	3	3	3
Average acre-treatments	1.02	1.28	1.07	1.31	1.22	1.17	1.15	1.73	1.19	1.18	1.23	1.23

nr = None reported.

1/ Excludes Long Island. 2/ The data were not tabulated to reveal insecticide-fungicide tank-mixes.

Table 47--Selected insecticides used in fall potato production, 1988

Item	CO	ID	ME	MI	MN	NY 1/	ND	OR	PA	WA	WI	Area
1,000 acres treated with insecticides	36	276	86	31	70	23	130	45	22	105	61	885
Percent acre-treatments by active ingredients: 2/												
Single materials--												
Aldicarb	nr	31	16	57	3	nr	1	61	57	68	3	26
Azinphos-methyl	nr	1	30	12	nr	11	nr	1	12	nr	2	4
Carbofuran	nr	3	nr	8	22	13	2	2	3	nr	nr	4
Disulfoton	2	5	25	nr	7	9	6	1	4	5	22	8
Endosulfan	6	1	33	9	13	30	24	nr	7	nr	9	10
Esfenvalerate	8	5	32	19	35	26	49	19	13	1	22	19
Ethoprop	nr	12	nr	2	nr	nr	nr	16	nr	7	nr	6
Fenvalerate	74	3	1	nr	66	20	23	1	24	7	51	18
Methamidophos	2	5	70	11	1	39	2	36	48	148	11	32
Permethrin	13	6	53	22	12	37	nr	26	6	18	25	16
Phorate	nr	39	nr	24	20	30	26	14	24	11	30	24
Phosphamidon	nr	nr	nr	nr	105	nr	129	nr	nr	nr	1	27
Other single materials	13	6	11	47	10	63	11	37	46	43	9	19
Tank mixes	6	7	4	24	3	46	2	11	72	3	nr	8
Average acre-treatments	1.23	1.24	2.75	2.34	2.95	3.44	2.73	2.25	3.16	3.11	1.86	2.20

nr = None reported.

1/ Excludes Long Island. 2/ The data were not tabulated to reveal insecticide-fungicide tank-mixes.

Table 48--Selected fungicides used in fall potato production, 1988

Item	CO	ID	ME	MI	MN	NY 1/	ND	OR	PA	WA	WI	Area
1,000 acres treated with fungicides	54	84	86	28	59	24	114	29	20	63	61	622
Percent acre-treatments by active ingredients: 2/												
Single materials--												
Chlorothalonil	49	26	78	5	21	6	nr	26	53	20	38	30
Mancozeb	5	22	397	67	105	51	52	22	134	19	182	108
Maneb	3	14	74	32	19	nr	[illegible]	10	4	nr	5	18
Maneb-zinc	22	32	298	84	93	55	65	24	71	11	97	88
Metalaxyl	nr	nr	24	5	nr	45	nr	2	13	7	3	7
Triphenyltin hydroxide	48	nr	nr	4	19	nr	53	nr	nr	1	52	21
Other single materials	7	5	nr	17	1	11	nr	66	nr	60	nr	12
Tank mixes--												
Mancozeb + metalaxyl	nr	nr	39	10	nr	36	nr	2	70	31	5	13
Mancozeb + triphenyltin	1	nr	1	nr	nr	nr	2	nr	nr	nr	91	10
Maneb + metiram	nr	3	nr	nr	15	nr	19	nr	nr	nr	nr	5
Maneb-zinc + triphenyltin	3	nr	nr	nr	[illegible]	nr	nr	nr	nr	nr	24	3
Other tank mixes	26	7	[illegible]	9	11	30	[illegible]	9	31	4	11	11
Average acre-treatments	1.63	1.14	9.19	[illegible].32	2.90	2.34	2.06	1.60	3.77	1.53	5.10	3.26

nr = None reported.

1/ Excludes Long Island. 2/ The data were not tabulated to reveal insecticide-fungicide tank-mixes.

treatment to be effective. A large share of the fall potatoes in the Pacific Northwest are treated with metribuzin because most of the crop is irrigated. Metribuzin is generally applied after planting but before the potatoes emerge. It controls such weeds as foxtail, ragweed, pigweed, and mustard.

EPTC was the second most commonly used herbicide. It is a selective herbicide that can be applied preplant or after planting prior to weed germination. It controls pigweeds, foxtails, and wild oats. EPTC must be incorporated into the soil because it is readily lost by volatization. It is most effective where rainfall is low, and is therefore more often used in dry areas.

Insecticides

Colorado potato beetles, aphids, and leafhoppers constitute the major insect problems in potato production. The Colorado potato beetle has developed some resistance to a number of organophosphorus insecticides, and to some of the newer synthetic pyrethroids.

The most commonly used insecticides across all States are esfenvalerate, fenvalerate, methamidophos, permethrin, and phorate (table 47). Aldicarb use is restricted in some areas of Maine and Wisconsin, and prohibited in Suffolk County, Long Island, New York because of groundwater considerations. Phosphamidon is used in Minnesota and North Dakota because it remains effective against the Colorado potato beetle and is inexpensive to use.

Fungicides

Mancozeb and maneb-zinc are the two most commonly used fungicides in fall potato production (table 48). Early and late blight are the two most serious diseases.

Early blight kills the potato vine, reducing the food supply available for tuber production in the hill. Late blight kills the vine, and can also infect developed tubers, making them vulnerable to decay in storage. In a potato hill with several vines, the blight organism may infect only some of them.

The disease organism is harbored in volunteer potato plants and in decaying vines and tubers left in the field from previous years. The disease organism can contaminate the potato plant when rain splashes infected soil particles onto the foliage.

Both mancozeb and maneb-zinc are protective fungicides—they must kill the disease organism before it invades the foliage. This explains the large number of fungicide treatments in high rainfall areas.

Common Crop Rotations Among Major Field Crops

by
Stan Daberkow and Mohinder Gill

Abstract: Crop rotations, rather than continuous cropping, are often proposed as a means to ameliorate environmental and economic concerns facing the agricultural sector. With the exception of Arkansas, Louisiana, Texas, and Mississippi 1988 cotton land, irrigated corn land in Nebraska, winter wheat land in Oklahoma, soybean land in Mississippi, and rice land in California, most cropland was involved in some type of rotation during the last 3 years. However, over 80 percent of the acreage planted to corn, soybeans, wheat, cotton, and rice in 1988 utilized only 5-10 rotations. Land used for potato production in 1988 grew a wider variety of crops in the previous 2 years. For some States and crops, only two or three rotations were widely practiced.

Keywords: Crop rotations, cropping patterns, best management practices, integrated pest management

Growing different crops on the same field or leaving the field fallow in a regular sequence is called a crop rotation. Advantages that may accrue to rotating crops include: legume rotations increase the nitrogen content of the soil; plant diseases, insects, and weeds can be more easily controlled; soil erosion, nutrient loss by leaching and runoff, and moisture loss are reduced; and organic matter and water-holding capacity of the soil may be increased (1). Such benefits as enterprise diversity and risk management are also associated with crop rotations. From an economic perspective, rotations may contribute to greater yields and profitability (2).

Despite the numerous benefits attributed to crop rotations, not all farmers employ this cultural practice. Agroclimatic conditions as well as economic factors underlie the decision to adopt a particular cropping practice. However, concern about water quality and food safety have prompted research programs and policy proposals to encourage more crop rotations. Best management practices, integrated pest management, USDA's Low Input Sustainable Agriculture (LISA) program, and such proposed legislation as the Farm Conservation and Water Protection Act of 1989 and the Conservation Enhancement and Improvement Act of 1989 all endorse crop rotations as one way to alleviate environmental and economic problems facing the agricultural sector.

This article, using data from the Cropping Practices Survey conducted by the National Agricultural Statistics Service (NASS), reports 3 year cropping patterns on land used for corn, wheat, cotton, soybean, rice, and potato production in 1988. Farmers have crop rotation goals, and as economic circumstances change, farmers reevaluate their land use pattern for each field. The 3 years presented here could be a complete rotation, part of a rotation, or more than one rotation.

Rotations on Land Producing Corn

Two common cropping patterns in the 10 major corn-producing States are continuous corn production and corn-soybeans-corn rotations (table A-1). These two patterns were used on nearly 65 percent of the 1988 corn acreage. In 1988, 26 percent of the corn land grew corn during the previous 2 years. The continuous corn pattern was most common in Nebraska (62 percent); 79 percent of the irrigated areas of the State reportedly use this pattern. Fixed investment in irrigation capital and heavy participation in the commodity programs have likely contributed to the lack of crop diversity on Nebraska's irrigated land. However, continuous corn is correlated with increased insecticide use (3).

The corn-soybeans-corn rotation dominated in Iowa (59 percent), Illinois (54 percent), Indiana (46 percent), and Minnesota (40 percent). For all States surveyed, 38 percent of the 1988 corn land grew soybeans in 1987 and corn in 1986. The ability of soybeans to fix nitrogen in the soil can allow farmers to reduce commercial nitrogen applications on the succeeding corn crop. Breaking the continuous corn cycle with soybeans also helps control weeds and insects (1).

In the dairy State of Wisconsin, alfalfa rather than soybeans alternates with corn production. In this State, 17 percent of the land used to grow corn in 1988 had been planted to alfalfa in the previous 2 years. Alfalfa serves the same purpose as soybeans in a rotation and provides protein for dairy cow rations. In South Dakota, where moisture can be a limiting factor, 36 percent of the 1988 corn acres had grown wheat or oats during the previous year. With the exceptions of Michigan and South Dakota, over 90 percent of the 1988 corn acreage was used in rotations involving wheat, alfalfa, corn, or soybeans.

Table A-1--Common crop rotations used on land producing corn, 1988

Previous crop 1987	1986	IL	IN	IA	MI	MN	MO	Nebraska State	Nebraska Dry	Nebraska Irr.	OH	SD	WI	Area
		Million acres planted												
		9.9	5.2	11.3	2.1	5.7	2.2	6.9	2.3	4.6	3.3	3.2	3.5	53.2
		Percent												
Corn	Corn	22	20	19	34	19	18	62	24	79	21	11	34	26
Corn	Soybean	5	11	4	5	4	7	4	6	3	8	2	5	5
Corn	Alfalfa	nr	1	4	3	3	2	1	4	nr	4	1	20	3
Corn	Other	nr	2	1	13	5	2	3	1	4	3	2	6	3
Wheat	Corn	nr	1	nr	nr	2	2	nr	1	nr	2	13	nr	1
Wheat	Other	2	3	nr	1	3	2	3	6	1	8	12	nr	3
Soybean	Corn	54	46	59	7	40	37	22	44	8	23	20	3	38
Soybean	Soybean	5	6	3	1	3	12	2	4	1	8	2	nr	4
Soybean	Other	3	1	1	7	3	9	nr	1	nr	7	7	2	3
Alfalfa	Alfalfa	2	1	4	6	7	2	nr	nr	1	5	1	17	4
Alfalfa	Other	1	1	3	1	nr	1	nr	nr	nr	3	nr	2	1
Oats	Corn	nr	nr	1	2	nr	nr	1	3	nr	1	10	1	1
Oats	Other	nr	nr	nr	2	1	nr	1	1	1	1	1	2	1
	Total	94	93	99	82	90	94	99	95	98	94	83	92	94

nr = None reported.

Rotations on Land Producing Winter Wheat

Much of the winter wheat grown in the United States is in the moisture-short area of the Great Plains. Hence, the moisture-conserving, wheat-fallow-wheat pattern is the most common rotation in this area. In 1988, 32 percent of the winter wheat acreage was fallowed in 1987 and planted to winter wheat in 1986 (table A-2). The States following this practice include Colorado (84 percent), Montana (62 percent), Washington (61 percent), Nebraska (54 percent), Oregon (50 percent), and Kansas (41 percent). Summer fallowing helps control weeds, insects, and plant diseases by interrupting their life cycles (1).

In parts of Texas and Kansas and in a large area of Oklahoma, enough moisture is available to permit continuous wheat growing. In Oklahoma, 70 percent of the acres harvested in 1988 were used for continuous wheat production, followed by Texas and Kansas with 41 and 17 percent, respectively.

In the more moisture abundant Corn Belt States, corn or soybeans are important components of winter wheat rotations. In Illinois, 62 percent of 1988 winter wheat acreage grew soybeans in 1987 and corn in 1986. In Indiana and Ohio, 59 and 47 percent, respectively, of the 1988 harvested winter wheat acres followed this rotation. Soybeans also comprised part of winter wheat rotations in Arkansas and Missouri. Yields of winter wheat and corn planted after soybeans can often be enhanced because of the soybean's nitrogen-fixing properties (1).

Montana, and to a much lesser extent Idaho and Washington, are the only States where a barley-fallow-wheat rotation is prominent. A sorghum-fallow-wheat rotation is popular in Kansas and Nebraska, reflecting the moisture constraints in this area. Sorghum is also grown in Texas and Missouri as part of a winter wheat rotation. Some rotation experiments have shown that crops following sorghum are likely to suffer yield losses due to sorghum's ability to extract moisture from the soil (1).

In California, Idaho, and Oregon, less than 75 percent of the winter wheat acreage is involved in rotations with corn, wheat, soybeans, or fallow. These States enjoy a wider variety of alternative rotation crops; alfalfa, vegetables, cotton, sugarbeets, or other specialty crops often form part of their winter wheat rotations. In Idaho and Washington, dry peas are common in winter wheat rotations, while vegetables are prominent in Oregon and California.

Rotations on Land Producing Spring Wheat

Land used for spring wheat production in 1988 showed a variety of cropping patterns. In Montana, 65 percent of 1988 spring wheat acreage was left fallow in the summer of 1987 and planted to wheat in 1986 (table A-3). North Dakota and Minnesota placed only 30 and 11 percent, respectively, of the 1988 spring wheat acreage under this rotation. In the five States surveyed, 49 percent of 1988 spring wheat crop was grown on land which was left idle in 1987.

Where rainfall or irrigation permit, more intensive crops were grown in the year that preceded spring wheat production. In Idaho, 24 percent of the spring wheat acres grew

Table A-2--Common crop rotations used on land producing winter wheat, 1987/88

Previous crop 1987	1986	AR	CA	CO	ID	IL	IN	KS	MO	MT	NE	OH	OK	OR	TX	WA	Area
		Million acres harvested															
		1.05	0.44	2.35	0.79	1.22	0.70	9.40	1.55	2.10	2.00	0.92	4.80	0.66	3.10	1.75	32.83
		Percent															
Corn	Soybean	nr	nr	nr	nr	6	6	nr	12	nr	nr	2	nr	nr	1	nr	1
Corn	Other	1	8	nr	1	7	17	nr	5	nr	nr	6	nr	1	6	2	2
Wheat	Wheat	1	8	2	2	nr	nr	17	nr	nr	nr	nr	70	4	40	3	20
Wheat	Other	3	7	4	13	3	nr	11	4	2	8	2	11	6	14	nr	8
Soybean	Wheat	16	nr	nr	nr	4	3	nr	10	nr	nr	6	nr	nr	nr	nr	1
Soybean	Soybean	31	nr	nr	nr	11	3	1	27	nr	nr	18	nr	nr	nr	nr	3
Soybean	Corn	nr	nr	nr	nr	62	59	1	7	nr	nr	47	nr	nr	nr	nr	5
Soybean	Other	15	nr	nr	nr	4	3	1	21	nr	nr	nr	1	nr	nr	nr	3
Fallow 1/	Wheat	1	11	84	20	nr	nr	41	nr	62	54	nr	7	50	10	61	32
Fallow	Barley	nr	nr	2	12	nr	nr	1	nr	24	nr	nr	nr	4	nr	14	3
Fallow	Sorghum	nr	nr	1	nr	nr	nr	17	6	nr	13	nr	1	nr	7	nr	7
Fallow	Other	17	13	3	4	1	8	4	4	10	19	2	5	10	7	3	6
Cotton	Other	nr	19	nr	nr	nr	nr	nr	1	nr	nr	nr	nr	nr	nr	nr	*
	Total	85	66	96	52	85	99	94	97	98	94	83	95	74	85	85	91

nr = None reported. * = Less than 1 percent.

1/ Fallow includes land idled under farm commodity program provisions.

Table A-3--Common crop rotations used on land producing spring wheat, 1988

Previous crop 1987	1986	Spring wheat ID	MN	MT	ND	SD	Area	Durum ND
		Million acres planted						
		0.38	2.00	1.50	4.60	1.30	9.78	2.50
		Percent						
Soybean	Corn	nr	10	nr	nr	nr	2	nr
Soybean	Wheat	nr	19	nr	2	11	6	1
Soybean	Other	nr	3	nr	4	nr	3	nr
Fallow 1/	Wheat	2	11	65	30	8	27	39
Fallow	Barley	nr	3	13	12	nr	8	18
Fallow	Other	4	9	1	20	11	14	20
Potatoes	Wheat	19	1	nr	1	nr	1	nr
Potatoes	Other	5	4	nr	nr	nr	2	1
Sugarbeet	Wheat	13	1	nr	3	nr	3	1
Corn	Other	4	5	nr	nr	24	4	1
Wheat	Other	22	14	17	10	16	13	15
	Total	69	80	96	82	70	83	96

nr = None reported.

1/ Fallow includes land idled under farm commodity program provisions.

potatoes in 1987, and 13 percent grew sugarbeets. In Minnesota, 32 percent of the spring wheat acres were planted to soybeans in 1987, while 24 percent of the acres in South Dakota grew corn. Both Idaho and South Dakota grew a variety of crops other than soybeans, potatoes, corn, and wheat in 1987.

North Dakota is the major State producing durum wheat, and 77 percent of the acreage planted to durum wheat in 1988 had been left fallow in the summer of 1987 (table A-3). This crop sequence reflects the moisture constraint farmers face in this area.

Rotations on Land Producing Soybeans

Soybeans, in addition to competing equally with other crops in terms of economic returns, provide a natural source of nitrogen and a nonchemical means of controlling insects in succeeding crops (such as rootworm in corn). Yields of corn and wheat crops planted after soybeans are, on average, 5-10 percent higher than those of corn and wheat crops planted after nonleguminous crops (1). The most common 3-year rotation practiced by farmers in most soybean States is soybeans-corn-soybeans: 41 percent of all 1988 soybean acreage grew corn in 1987 and soybeans in 1986. In Iowa, 74 percent of the 1988 soybean crop followed this rotation, followed by Illinois (61 percent), Minnesota (51 percent), Nebraska (43 percent), and Indiana (41 percent) (table A-4).

Continuous soybean production was practiced on over one-third of the 1988 soybean acreage in Arkansas, Louisiana, Mississippi, Missouri, Georgia, and Tennessee. In contrast, only 15 percent of the 1988 soybean acreage in all 14 soybean-producing States was continuously planted to soybeans. This appears to be a profitable practice in the Southern States, although soybeans in the South receive more herbicide treatments than in the North (3). On the other hand, very little insecticide is used on soybeans grown in the South (2).

Rice constituted a significant part of a soybean rotation in Louisiana and Arkansas. About 10 to 15 percent of the 1988 soybean land was fallow in 1987 in Arkansas, Georgia, Louisiana, and Mississippi.

In the transition States between the North and South, both continuous soybean production and soybean-corn-soybean rotations are common. Kentucky, North Carolina, and Missouri had over 40 percent of their soybean acreage devoted to these two rotations. These rotations were also used on Ohio soybean acreage, but to a lesser extent. Ohio had a large share (24 percent) of its soybean acreage in a corn-soybeans-soybeans rotation.

Rotations on Land Producing Rice

Rice crop rotation practices vary widely among States. In Arkansas and Louisiana, common rotations are rice-soybeans-rice and rice-soybeans-soybeans (table A-5). In these States, 20 percent of the 1988 rice acreage was planted to soybeans during the previous 2 years; another 20 percent

Table A-4--Common crop rotations used on land producing soybean, 1988

Previous crop 1987	1986	AR	GA	IL	IN	IA	KY	LA	MN	MS	MO	NE	NC	OH	TN	Area
		Million acres planted														
		3.25	0.9	8.8	4.3	7.95	0.98	1.8	4.9	2.4	4.3	2.4	1.47	3.9	1.4	48.75
		Percent														
Soybean	Corn	nr	7	7	16	6	18	10	7	1	17	12	9	24	8	10
Soybean	Soybean	40	34	5	9	3	8	44	2	58	24	3	16	11	38	15
Soybean	Other	13	7	nr	2	1	2	7	3	18	7	2	4	8	6	4
Corn	Corn	nr	8	11	19	7	13	4	7	nr	6	17	4	7	4	8
Corn	Soybean	1	4	61	41	74	34	nr	51	1	24	43	32	30	9	41
Corn	Other	nr	3	4	3	5	11	nr	6	nr	3	8	8	9	9	4
Wheat	Other	1	11	3	2	1	9	2	10	2	5	8	6	6	8	4
Rice	Soybean	17	nr	nr	nr	nr	nr	14	nr	4	nr	nr	nr	nr	nr	2
Rice	Other	5	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
Fallow 1/	Other	9	10	5	4	3	1	13	4	15	3	1	6	2	4	5
	Total	86	84	96	96	100	96	94	90	99	89	94	85	97	86	93

nr = None reported.

1/ Fallow includes land idled under farm commodity program provisions.

was planted to soybeans in 1987 and rice in 1986. Overall, 44 percent of the 1988 rice land grew soybeans in 1987.

In California, however, the most popular patterns are continuous rice and rice-fallow-rice. An estimated 72 percent of the 1988 rice land in California followed continuous rice production, 8 percent a rice-fallow-rice rotation, and 6 percent a rice-fallow-fallow rotation. In the Delta States, disease, insect, and weed problems prohibit widespread use of the continuous rice pattern. In contrast, most California rice is grown on heavy soils that offer few economic alternatives and on land specifically leveled for rice production.

Table A-5--Common crop rotations used on land producing rice, 1988

Precious crop 1987	1986	AR	CA	LA	Area
		Millon acres planted			
		1.18	0.42	0.53	2.13
		Percent			
Soybean	Soybean	29	nr	15	20
Soybean	Rice	30	nr	15	20
Soybean	Other	5	nr	4	4
Fallow 1/	Rice	10	8	17	11
Fallow	Fallow	5	6	8	6
Fallow	Other	5	nr	5	4
Rice	Rice	3	72	8	18
Rice	Other	11	2	11	10
	Total	98	94	83	93

nr = None reported.

1/ Fallow includes land idled under farm commodity program provisions.

Rotations on Land Producing Cotton

Continuous cotton cropping is widely practiced in the six major cotton-producing States (table A-6). Fifty-seven percent of the 1988 cotton land grew cotton in the previous 2 years. In Louisiana, Mississippi, Arkansas, and Texas, 78, 75, 64, and 56 percent, respectively, of the 1988 cotton land followed this cropping pattern. In Arizona and California, only about 40 percent of the 1988 cotton land was planted to cotton in 1987 and 1986. The Delta States average three or more herbicide treatments per acre, whereas the other States apply herbicides slightly more than once per acre (3). Despite increased weed pressures, continuous cotton remains the most economic cropping practice in these States.

Due to the diverse crop opportunities in California and Arizona, less than 75 percent of the acreage was placed in a common rotation pattern. In contrast to rice, insect and weed problems prevent widespread use of the continuous cotton pattern in California. Also, unlike rice, economical alternative uses for cotton land exist.

Rotations on Land Producing Fall Potatoes

U.S. fall potato production occurs in a variety of agroclimatic circumstances from Maine to Washington. Potato rotations reflect pest management practices, the availability of other crops, and economic conditions in the various growing regions. Less than 5 percent of 1988 potato acreage grew potatoes in 1987 and 1986 (table A-7). Almost 40 percent of the 1988 potato acreage grew wheat in 1987, and about 20 percent grew barley. The most homogeneous cropping pattern occurred in Colorado, where 68 percent of the potato acreage grew barley in 1987 and potatoes in 1986. A significant regional demand for barley for Coors beer pro-

Table A-6--Common crop rotations used on land producing cotton, 1988

Previous crop 1987	1986	AZ	AR	CA	LA	MS	TX	Area
		Million acres planted						
		0.34	0.68	1.40	0.70	1.20	5.40	9.70
		Percent						
Sorghum	Other	nr	nr	nr	nr	2	12	7
Soybean	Soybean	nr	12	nr	3	4	nr	2
Soybean	Other	nr	9	nr	6	6	nr	1
Cotton	Cotton	38	64	43	78	75	56	57
Cotton	Fallow 1/	21	nr	3	2	4	3	3
Cotton	Other	13	13	18	8	6	11	12
	Total	72	98	64	97	97	82	82

nr = None reported.

1/ Fallow includes land idled under farm commodity program provisions.

Table A-7--Common crop rotations used on land producing potatoes, 1988

Previous crop 1987	Previous crop 1986	CO	ID	ME	MI	MN	NY	ND	OR	PA	WA	WI	Area
		Million acres planted											
		0.06	0.35	0.09	0.03	0.07	0.03	0.13	0.05	0.02	0.12	0.06	1.01
		Percent											
Corn	Corn	nr	1	1	1	2	1	1	3	8	3	10	2
Corn	Wheat	nr	nr	nr	1	nr	nr	nr	4	1	11	nr	1
Corn	Potatoes	nr	nr	2	15	nr	nr	1	nr	8	14	3	3
Corn	Other	nr	nr	nr	4	1	3	nr	3	3	6	6	1
Wheat	Corn	nr	nr	nr	nr	nr	nr	nr	7	1	5	nr	1
Wheat	Wheat	1	26	nr	nr	6	nr	10	4	nr	5	nr	11
Wheat	Barley	nr	4	nr	nr	6	nr	8	2	nr	nr	nr	3
Wheat	Fallow	nr	nr	nr	nr	2	nr	8	3	nr	nr	nr	1
Wheat	Potatoes	10	14	nr	4	9	5	19	10	12	4	nr	10
Wheat	Other	nr	5	nr	nr	12	3	11	7	nr	14	nr	12
Barley	Wheat	nr	3	nr	nr	16	nr	19	nr	nr	nr	nr	5
Barley	Barley	3	10	1	nr	2	nr	9	10	nr	nr	nr	5
Barley	Potatoes	68	11	nr	1	4	nr	1	6	nr	nr	nr	9
Barley	Other	2	2	nr	nr	8	nr	2	5	nr	nr	nr	2
Fallow 1/	Other	5	5	2	5	9	1	10	13	4	3	nr	5
Alfalfa	Alfalfa	nr	11	1	3	nr	1	nr	11	3	11	4	6
Alfalfa	Other	nr	4	8	2	nr	nr	nr	nr	9	1	9	3
Oats	Potatoes	1	nr	44	16	nr	15	nr	1	13	nr	3	5
Oats	Other	nr	nr	6	9	1	nr	nr	nr	5	nr	6	2
Potatoes	Oats	nr	nr	17	3	1	1	nr	nr	3	nr	2	2
Potatoes	Potatoes	2	1	8	11	3	25	nr	1	1	nr	3	3
Potatoes	Other	6	3	7	6	2	18	nr	1	3	6	6	3
Vegetable	Vegetable	nr	nr	nr	nr	nr	6	nr	nr	nr	1	21	2
	Total	98	100	97	81	84	79	99	91	74	84	73	97

nr = None reported.

1/ Fallow includes land idled under farm commodity program provisions.

duction makes this an attractive crop to rotate with potatoes in Colorado.

Roughly two overlapping regional rotation patterns for potatoes were evident in 1988. The Northeast potato States (Maine, New York, and Pennsylvania), Michigan, and Wisconsin grew significant amounts of oats or potatoes in 1987. Colorado, North Dakota, Minnesota, Idaho, Oregon, and Washington used wheat and barley widely in their 1987 potato rotations. However, several States—including Wisconsin, Michigan, Pennsylvania, Oregon, and Washington—grew corn in 1987 as part of their potato rotations. Alfalfa was also common in the potato rotations of Washington, Idaho, Oregon, Wisconsin, and Pennsylvania. In Wisconsin potatoes were often grown in rotation with other vegetable crops during the previous 2 years. Continuous potato production was reported on 25 percent of the 1988 potato acreage in New York, where the lack of equally profitable crops, combined with high-priced land, discourages rotations. In Oregon and Pennsylvania, less than 75 percent of the 1988 potato acreage fell into the major rotation categories.

Conclusion

Some concern has been expressed that our most intensively farmed land is being subjected to continuous or monoculture cropping, which may be deleterious to long-term soil productivity. However, it is clear that among the major U.S. crops, continuous cropping is not a prevalent practice. Only in the case of cotton was the same crop grown on the same land for at least 3 consecutive years; this practice was used on over 50 percent of the 1988 acreage. For the remaining crops, the rotations did not demonstrate a high degree of diversity. For most crops in most States, 5 to 10 rotations were used on 80 percent or more of the cropland. In many States, only 2 or 3 rotations were widely used.

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Timing of Fertilizer Applications

by
Harold Taylor and Harry Vroomen

Abstract: The number and timing of fertilizer applications used in the production of 1988 corn, cotton, soybeans, and wheat was determined from a survey of the major producing States. Results indicate that the average number of fertilizer treatments ranged from 1.21 per acre for soybeans to 2.17 for corn. Most of the fertilizer was applied to winter wheat in the fall before seeding, whereas the other crops received most of their fertilizer by spring, before seeding. Corn, for example (which accounted for an estimated 44 percent of total nutrient use in 1988), received 70 percent of its nitrogen, 64 percent of its phosphate, and 81 percent of its potash by seeding time. Sixteen percent of all the nitrogen used on corn was applied in the fall. While only 23 percent of the 1988 corn acres planted were fertilized with nitrogen in the fall, the average application rate was 100 pounds per acre, indicating potential environmental problems for some areas. However, 84 percent of nitrogen was applied near the time of plant use, thus reducing the potential for environmental damage.

Keywords: Timing of fertilizer applications, acre-treatments, nitrogen, phosphate, potash

Widespread public concern exists that agricultural practices are contributing to the contamination of the nation's surface water and groundwater. Most agriculturally induced pollution is nonpoint-source pollution (NPSP), meaning the specific source cannot be identified (6). Fertilizer and pesticide contamination of groundwater has already led to numerous policy proposals affecting agriculture. The 1987 Water Quality Act, for example, instructs States to identify NPSP contributing to waterway degradation and to recommend "best management practices" to improve waterway quality (5). Consequently, major emphasis has been placed on best management practices to reduce ground and surface water contamination. These practices include, but are not limited to, crop rotations, conservation tillage, contouring, terracing, soil testing, and timing and placement of fertilizer nutrients.

This article focuses on the timing of fertilizer applications. During field preparations and the growing season, many major crops receive more than one application. Corn, for example, often receives a mixed fertilizer during or before planting, and a second application about 20 or 30 days after emergence of the seedlings (3). In contrast, soybeans are generally treated only once with fertilizer.

From both an economic and environmental perspective, fertilizer applications should be timed for maximum efficiency. Agronomic studies suggest that properly timed nutrient applications, especially nitrogen, can boost yields and reduce leaching by making the fertilizer available when crop use is highest (1, 2). Properly timed nutrient applications thus have the potential to increase yields and decrease environmental contamination, since fewer nutrients are allowed to run off into surface water or leach into underground aquifers.

While agronomic studies can be employed to determine the proper timing of nutrient applications for a given crop in various environments, information on fertilizer timing practices of U.S. farmers is also useful. Detailed 1988 data on the timing of nutrient applications and the number of fertilizer treatments have been tabulated for four crops. Fertilizer application data on corn, cotton, soybeans, and wheat were obtained in the 1988 Cropping Practices Survey conducted by NASS. The survey covers the principal producing States, which account for 79-86 percent of the planted acres (harvested acres for winter wheat) of these crops.

Number of Treatments

In the 10 corn States surveyed (representing 53.2 million acres of planted corn), an average of 2.17 fertilizer acre-treatments were made in 1988, the highest among the selected crops (table B-1). Of the estimated 51.6 million corn acres treated in the 10 States, 26 percent were treated once, 40 twice, and 27 three times. In contrast, soybeans received the lowest average number of acre-treatments—1.21. In the 14 surveyed States, 80 percent of the estimated 15.6 million soy-

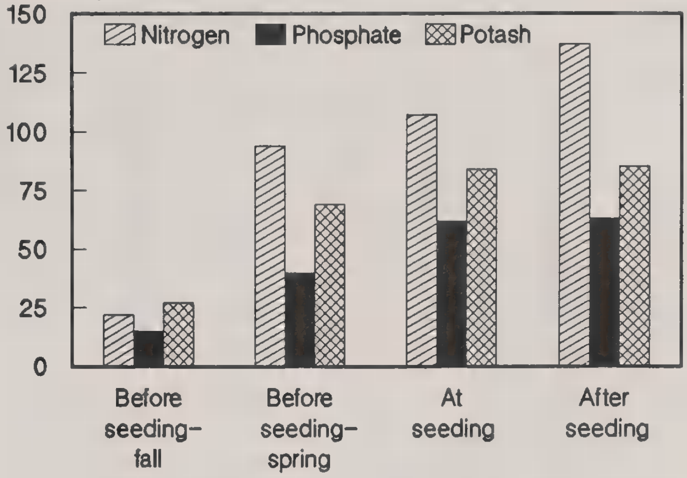
Table B-1--Percent of selected crop acres treated with fertilizer by number of treatments, 1988 1/

Crop	Number of treatments 1	2	3	4	>4	Average acre-treatments
	Percent 2/					
Corn	26	40	27	6	1	2.17
Cotton	52	37	9	2	1	1.64
Soybeans	80	19	1	nr	nr	1.21
Wheat:						
Winter	50	41	8	1	#	1.60
Spring	58	38	4	nr	nr	1.45
Durum	65	34	1	nr	nr	1.36

nr = None reported. # = Less than 0.5 percent.

1/ Specific States surveyed for each crop are listed in tables B-2 through B-5. 2/ May not sum to 100 due to rounding.

Figure B-1
Cumulative distribution of fertilizer applications on 1988 corn



bean acres treated received only one application of fertilizer, while 19 percent received two applications. Fertilizer acre-treatments averaged 1.64 for cotton, and ranged on wheat acres from 1.36 (durum wheat) to 1.60 (winter wheat).

Timing of Applications

There are numerous reasons why growers may want to split their fertilizer applications, the most important of which is the plant's agronomic requirements. Applications may also be split to reduce potential environmental damage. Other factors may be more related to economic considerations, however. The price of fertilizer is typically higher in the spring than in the preceding fall due to seasonal demand factors. For example, over the period 1961-88, anhydrous ammonia, concentrated superphosphate, and potassium chloride prices paid by farmers averaged 6, 5, and 5 percent higher in the spring than in the preceding fall (7). Consequently, some farmers purchase and apply fertilizer in the fall to cut costs.

Farmers may also apply fertilizer more than once to make timely use of available resources. Aside from winter wheat, spring planting typically places high seasonal demands on a grower's time, machinery, and hired and nonhired labor. Therefore, to spread out the demand for these resources, the grower may decide to apply some fertilizer in the fall. Fall fertilization can also reduce risks associated with wet springs. Additionally, some forms of irrigation technology can easily provide more than one fertilizer application.

Data from the Cropping Practices Survey were used to determine the timing of fertilizer applications by crop and nutrient. The survey permits the timing of nutrient applications to be separated into four categories: (1) before seeding in the fall; (2) before seeding in the spring; (3) at seeding; and (4) after seeding. Average per-acre rates by nutrient were calculated for each of the four designated times for each selected crop. This breakdown allows an analysis of how the overall nutrient application rate for a particular crop is distributed over the time periods.

Corn

Fertilizer was applied to 97 percent of the 53.2 million corn acres planted in the 10 surveyed States in 1988: 97 percent of the acres received nitrogen, 87 received phosphate, and 78 received potash (8). Average application rates for those corn acres receiving a particular nutrient stood at 137 pounds per acre for nitrogen, 63 pounds for phosphate, and 85 pounds for potash.

Table B-2 and fig. B-1 indicate how these nutrients were distributed over the four time periods on the 1988 corn crop. An average of 22 pounds (16 percent) of nitrogen per acre was applied in the fall before seeding, 72 pounds (53 percent) in the spring before seeding, 13 pounds (10 percent) at seeding, and 29 pounds (21 percent) after seeding. Results were similar for phosphate and potash because in general most of these nutrients were applied before seeding in the spring. However, unlike nitrogen, little phosphate or potash was applied to corn after seeding.

The distribution of nutrient applications also varied among States. In Wisconsin, only 5, 8, and 18 percent of the total nitrogen, phosphate, and potash used, respectively, was applied in the fall. However, these shares increased to 30, 31, and 33 percent in South Dakota, where a dry fall in 1987 and less potential for nitrogen leaching during the winter encouraged fall fertilization. In contrast, 42 percent of the nitrogen and 91 percent of the phosphate used in Michigan was applied at seeding.

Cotton, Soybeans, and Wheat

Tables B-3 through B-5 present the distributions of nutrient applications for cotton, soybeans, and wheat. Although the

Table B-2--Distribution of nutrient application rates on corn by time of application, 1988

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
IL	9,900	35	93	6	29	33	47	6	#	43	62	4	1
IN	5,200	16	65	22	44	12	19	39	nr	32	62	19	#
IA	11,300	23	92	5	20	19	29	8	2	30	41	5	2
MI	2,100	11	33	30	54	#	5	56	nr	24	38	38	3
MN	5,700	23	64	12	18	10	21	20	#	11	31	20	2
MO	2,200	25	78	14	15	13	34	10	1	16	42	10	1
NE	6,900	26	68	13	35	4	7	26	1	2	6	8	7
OH	3,300	6	59	29	59	10	23	47	nr	38	47	26	#
SD	3,150	24	35	10	11	12	16	10	nr	9	12	5	nr
WI	3,450	5	31	27	22	6	6	43	nr	14	13	46	1
Area	53,200	22	72	13	29	15	25	22	1	27	42	15	1

nr = None reported. # = Less than 0.5 pounds.

Table B-3--Distribution of nutrient application rates on cotton by time of application, 1988

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
AZ	340	17	9	5	113	22	25	1	11	2	9	nr	3
AR	680	7	38	2	32	13	29	1	2	12	42	3	1
CA	1,350	44	38	4	39	18	16	4	7	15	15	5	5
LA	700	11	27	3	47	13	30	2	7	16	34	2	6
MS	1,230	25	28	5	53	8	29	11	1	12	39	7	1
TX	5,400	10	19	2	13	11	21	#	5	2	9	#	2
Area	9,700	18	25	3	32	12	23	2	5	9	25	3	2

nr = None reported. # = Less than 0.5 pounds.

Table B-4--Distribution of nutrient application rates on soybeans by time of application, 1988

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
AR	3,250	9	14	4	nr	24	17	1	2	30	27	2	4
GA	900	9	3	2	1	22	10	3	1	44	26	5	1
IL	8,800	9	8	5	nr	37	27	3	nr	52	44	5	nr
IN	4,300	2	9	5	2	5	21	13	nr	22	39	17	nr
IA	7,950	6	15	2	nr	19	8	6	nr	25	33	6	nr
KY	980	15	15	9	#	26	27	16	1	30	27	21	1
LA	1,800	1	16	1	nr	1	29	11	nr	1	45	16	nr
MN	4,900	6	12	4	nr	22	17	10	9	19	25	7	nr
MS	2,400	17	18	2	nr	15	20	6	nr	22	40	7	nr
MO	4,300	13	9	1	2	15	29	5	1	21	45	6	2
NE	2,400	7	9	15	1	nr	6	18	nr	nr	5	11	nr
NC	1,470	3	4	6	#	5	13	13	1	22	27	21	2
OH	3,900	1	6	10	#	14	23	9	#	46	47	10	#
TN	1,400	7	24	2	#	14	24	5	1	17	36	7	1
Area	48,750	6	10	5	1	18	21	8	1	31	37	10	1

nr = None reported. # = Less than 0.5 pounds.

Table B-5--Distribution of nutrient application rates on wheat by time of application, 1988

State	Acres 1/	Nitrogen: Before seeding: Fall	Nitrogen: Before seeding: Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding: Fall	Phosphate: Before seeding: Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding: Fall	Potash: Before seeding: Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
		Winter wheat											
AR	1,050	6	na	1	87	22	na	2	14	22	na	#	20
CA	440	73	na	#	17	46	na	9	nr	id	id	id	id
CO	2,350	40	na	#	2	14	na	#	#	id	id	id	id
ID	790	41	na	18	43	19	na	9	6	10	na	#	7
IL	1,220	35	na	2	60	75	na	#	#	93	na	#	#
IN	700	25	na	5	42	44	na	12	1	54	na	18	4
KS	9,400	38	na	#	13	20	na	12	#	13	na	12	#
MO	1,550	27	na	10	54	35	na	13	4	44	na	16	#
MT	2,100	29	na	#	#	4	na	25	1	22	na	#	nr
NE	2,000	31	na	1	13	23	na	#	#	id	id	id	id
OH	920	14	na	7	50	35	na	18	7	46	na	19	10
OK	4,800	46	na	#	21	21	na	7	1	12	na	#	1
OR	660	46	na	3	24	19	na	14	#	18	na	16	2
TX	3,100	51	na	3	27	31	na	6	2	20	na	nr	4
WA	1,750	58	na	#	#	15	na	#	4	16	na	nr	16
Area	32,830	38	na	4	24	26	na	11	2	43	na	10	#
		Spring wheat											
ID	380	36	52	4	6	16	26	4	#	id	id	id	id
MN	2,000	40	36	12	#	6	11	20	1	5	15	11	1
MT	1,500	12	3	9	1	2	1	18	nr	id	id	id	id
ND	4,600	18	20	12	1	#	6	24	nr	nr	9	#	nr
SD	1,300	12	16	14	nr	2	12	11	nr	id	id	id	id
Area	9,780	23	23	12	1	3	#	20	#	3	13	10	1
		Durum wheat											
ND	2,500	14	18	7	1	1	4	21	nr	id	id	id	id

na = Not applicable. nr = None reported. id = Insufficient data. # = Less than 0.5 pounds.

1/ Harvested acres for winter wheat and planted acres for spring and durum wheat.

nutrient distributions for these crops generally resemble those of corn, some differences are apparent. As with corn, most of the nutrients applied to cotton, soybeans, and wheat were before seeding. However, in the case of cotton, only a small proportion of total nutrient use was applied at seeding. Very little fertilizer was applied to soybeans and spring wheat after seeding.

Fertilizer Treatments on Corn

U.S. farmers use more fertilizer on corn than on any other crop. During the 1987/88 fertilizer year (July 1-June 30), they applied an estimated 8.6 million tons of primary plant nutrients to their corn acres, or about 44 percent of total nutrient consumption (7). Specifically, corn production accounted for an estimated 43 percent of the nitrogen and 45 percent of the phosphate and potash used in 1987/88. Due to the importance of the corn crop for fertilizer use, fertilizer treatments on corn by nutrient and time of application are discussed in more detail.

Table B-2 shows how, on average, the total quantity of each nutrient applied to corn in 1988 was distributed throughout the production season. Although it provides useful information, a more detailed analysis of nutrient use by time of application supplies additional data that may be used to characterize current production practices and develop policies that could be effective in combating surface and groundwater contamination. These statistics include: (1) the proportion of acres which received fertilizer during a particular time period, by nutrient; and (2) the average nutrient application rate of only those acres which received a particular nutrient during any selected time period.

Table B-6 shows the proportion of corn acres that received fertilizer in each time period by nutrient. For example, of the corn acres which received nitrogen, 23 percent received some nitrogen in the fall before seeding, 59 percent received some in the spring before seeding, 45 percent received some at seeding, and 27 percent received some after seeding. Since farmers can apply fertilizer during one or more time periods, the sum of these percentages exceeds 100 for each nutrient.

Table B-6--Percent of corn acres receiving fertilizer by nutrient and time of application, 1988

State	Acres planted	Nitrogen: Before seeding Fall	Nitrogen: Before seeding Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding Fall	Phosphate: Before seeding Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding Fall	Potash: Before seeding Spring	Potash: At seeding	Potash: After seeding
	1,000	Percent 1/											
IL	9,900	33	64	16	22	38	53	15	#	38	57	10	#
IN	5,200	15	52	71	42	20	33	75	nr	28	52	44	1
IA	11,300	25	74	24	20	29	49	24	4	32	52	17	4
MI	2,100	10	30	90	47	1	9	92	nr	22	32	72	2
MN	5,700	23	62	55	17	16	36	58	1	15	42	53	2
MO	2,200	22	65	20	15	23	57	18	4	22	60	17	5
NE	6,900	22	58	59	31	9	21	74	3	9	19	77	7
OH	3,300	11	52	78	49	14	28	76	nr	32	39	55	1
SD	3,150	30	50	30	14	29	43	31	nr	30	49	24	nr
WI	3,450	11	35	87	28	6	13	80	nr	12	19	66	#
Area	53,200	23	59	45	27	22	38	48	2	27	46	38	2

nr = None reported. # = Less than 0.5 percent.

1/ The sum of the percentages exceeds 100 for each nutrient because growers can apply fertilizer during one or more time periods.

Table B-7--Average application rates on corn for those acres receiving specific nutrients by time of application, 1988

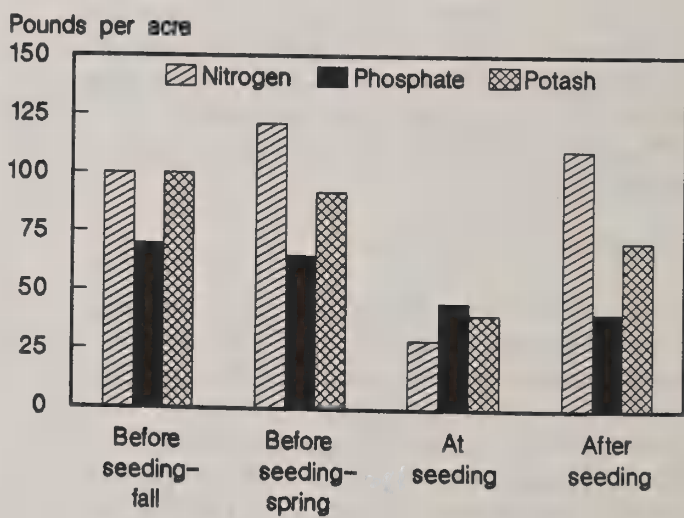
State	Acres planted	Nitrogen: Before seeding Fall	Nitrogen: Before seeding Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding Fall	Phosphate: Before seeding Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding Fall	Potash: Before seeding Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
IL	9,900	108	145	39	132	87	90	41	46	113	109	42	120
IN	5,200	111	125	31	105	61	58	53	nr	114	118	42	65
IA	11,300	90	124	21	101	66	58	34	46	92	79	30	46
MI	2,100	109	112	34	114	40	63	60	nr	111	122	53	120
MN	5,700	100	103	22	105	65	59	35	28	77	74	38	120
MO	2,200	114	120	71	103	56	60	58	34	74	70	62	28
NE	6,900	121	117	22	112	42	36	35	37	19	33	11	97
OH	3,300	56	115	37	121	74	81	62	nr	121	119	47	56
SD	3,150	80	70	33	77	41	37	33	nr	29	24	23	nr
WI	3,450	43	90	31	80	71	51	48	nr	123	71	54	108
Area	53,200	100	121	29	110	70	65	45	41	100	92	40	71

nr = None reported.

Further analysis suggests that fall fertilization on some corn acreage has the potential to cause environmental problems. Table B-7 and fig. B-2 show average nutrient application rates for only those acres that received a particular nutrient during a selected time period. For example, the nitrogen application rate for corn acres receiving nitrogen in the fall before seeding averaged 100 pounds per acre. Overall, almost 16 percent of the total nitrogen used on the 1988 corn crop was applied in the fall.

Nitrogen application rates for corn growers who applied fertilizer on 59 percent of the corn acres before seeding in the spring averaged 121 pounds per acre. The total amount of these applications in this time period represented about 50 percent of the nitrogen applied during the year. About 12 percent of the nitrogen applied during the year was applied at seeding; another 22 percent was applied after seeding. The average application rate for those growers who applied at seeding and after seeding was 29 and 110 pounds per acre, respectively. Since different numbers of farmers applied fertilizer during the different time periods, these averages are not additive, and their sum does not equal the yearly application rate for all farmers applying fertilizer during the year.

Figure B-2
Fertilizer application rates on corn



Results were similar for phosphate and potash, but the average application rates for these nutrients were highest in the fall. Growers who applied phosphate in the fall used an average of 70 pounds per acre, while those who used potash

applied an average of 100 pounds per acre. In addition, few corn acres received either phosphate or potash after seeding.

Average nutrient application rates by time of application also varied significantly among States. Fall nitrogen applications ranged from an average of 43 pounds in Wisconsin to 121 pounds in Nebraska, a State experiencing significant groundwater contamination problems. Similarly, fall applications for phosphate varied from 40 to 87 pounds, and those for potash ranged from 19 to 123 pounds among States. The information in table B-7 has important implications for determining best management practices for effective timing of fertilizer applications. For example, spring 1988 denitrification and leaching may have prohibited corn crop utilization of a substantial portion of the nitrogen applied in the fall.

Denitrification (the gaseous loss of nitrogen) is a major mechanism of nitrogen loss in waterlogged and poorly aerated soils in which aerobic and anaerobic conditions fluctuate. Denitrification losses of 50 percent or more of applied nitrogen are common (4). The loss of nitrogen through percolation is also possible, since soils and subsoils have little capacity to retain nitrate. Therefore, nitrate loss depends on the concentration of nitrogen escaping below the root zone and the flux of percolating water moving it. This phenomenon is particularly evident until the soil freezes during the winter months or after it thaws in the spring. The time lapse between fall fertilization and spring planting increases the likelihood that nitrogen will percolate into groundwater when it is applied to corn in the fall.

Implications

The timing of fertilizer applications has important agronomic, economic, and environmental ramifications. Price incentives, resource limitations, and the potential for a wet spring, among other things, can encourage farmers to apply some fertilizer in the fall. Using phosphate or potash in the fall does not pose an environmental problem, because these nutrients are relatively immobile in soils that are not prone to erosion. However, nitrogen used for fall fertilization is subject to denitrification, and may run off into surface water or leach into underground aquifers.

U.S. farmers use more nitrogen on corn than on any other crop. During the 1988 fertilizer year, the production of corn accounted for an estimated 4.5 million tons of nitrogen, or about 43 percent of the total. In the 10 major producing States, 23 percent of the acres planted to corn (12 million acres) were treated with nitrogen in the fall. This area received an average of 100 pounds of nitrogen per acre, and accounted for 16 percent of all the nitrogen applied to corn. Although only 16 percent of the total nitrogen used was applied in the fall, average nitrogen application rates were relatively high, indicating the potential for environmental problems.

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